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PHYSIOLOGICAL AGE

THE WORK OF C. WARD CRAMPTON, M.D.

Editorial Note

Some thirty-six years ago Dr. C. Ward Crampton published a paper, "Physiological Age - A Fundamental Principle" in the American Physical Education Review (Vol. XIII, Nos. 3, 4, 5, 6, 1908) containing the results of the work of seven years on this subject. It includes the substance of his earlier reports: "Pubescence," American Anthropologist, Vol. 6, No. 5, 1904, Prize Winning Thesis, Olympic Congress, St. Louis Exposition, 1904, and the "Influence of Physiological Age upon Scholarship," Psychological Clinic, Vol. I, No. 4, June, 1907. It deals in particular with the significance of the different stages of puberty for the physical growth and mental development of children of the same chronological age. Since his investigations may still today have a far-reaching meaning and represent to a certain degree the summary of one phase of his life work, the findings on New York school boys deserve to be recalled. Therefore, it seems to be worth having the paper republished in Child Development all the more because the original is hardly still available to many readers interested in the matter.

In the following pages the original paper is reproduced with only some smaller alterations. The author, realizing that

few of his readers would be familiar with the new biometric methods, preceded his main paper with a thorough simple presentation of the statistical methods used (American Physical Education Review, Vol. XIII, No. 1, 1908, 12 pages).

The findings and computations of the author are given untouched; some of his tables and charts in the appendices are left out to save space - they do not concern the material dealt with in the text proper. In reproducing the charts and tables, the original numbers were retained. Furthermore, it appeared to be reasonable to put ahead of the whole paper the introductory pages of the last section (No. IV) entitled "Significant Features of Life Centering About Puberty," which deal with some of the older literature and give quite an impressive introduction to the problem later discussed in detail by Dr. Crampton.

C.E.P.

PHYSIOLOGICAL AGE - A FUNDAMENTAL PRINCIPLE

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INTRODUCTION: SIGNIFICANT FEATURES OF LIFE CENTERING ABOUT PUBERTY (SECTION IV)

The features of weight, height, strength, and scholarship are the indices of profound physical changes during puberty. An acceleration of growth rate means an upheaval of the whole being. All organs are put under new conditions. It is a significant fact that morbidity increases at this period, though mortality does not. It is unnecessary to go further to emphasize the tremendous significance of the features of this period to the physician. A mere catalogue of some of the changes asserted to take place at this time is pertinent.

Marro (La Puberté) catalogues in girls the pubic and axillary pubescence, development of the breasts and menstruation. (See Chart I, p. 4); also in boys pubic, axillary, and labial pubescence. (Chart II, p. 5.) His series are too small for definite results. He also considers change of voice. (See Chart III, p. 6.)

"At or about puberty" the bones increase rapidly in length and girth.* Moon finds that the legs increase most rapidly in length before puberty, the body afterward. West, Porter, Hrdlička, Peckham, and Smedley found various results on this comparative growth. Throughout the body various bones begin to lengthen and show junction of epiphysis and shaft or body. Ossification is accelerated and completed, but by no means uniformly.

Canine teeth, back premolars and second molars all have their period of change from 11 to 16 years. The lower jaw grows longer and the head changes in many ways.

Before puberty the blood vessels are large and the heart small. The heart increases at this time at a far greater rate than the arteries. This is a most important point and may account for the increase of blood pressures at this stage and for the very characteristic functional affections of the heart. Sexual differences in blood-count become evident at puberty, and anaemias of the chlorotic type are characteristic. The pulse rate is increased during "puberty" (?).

The "capacity" of the lungs is increased rapidly at this

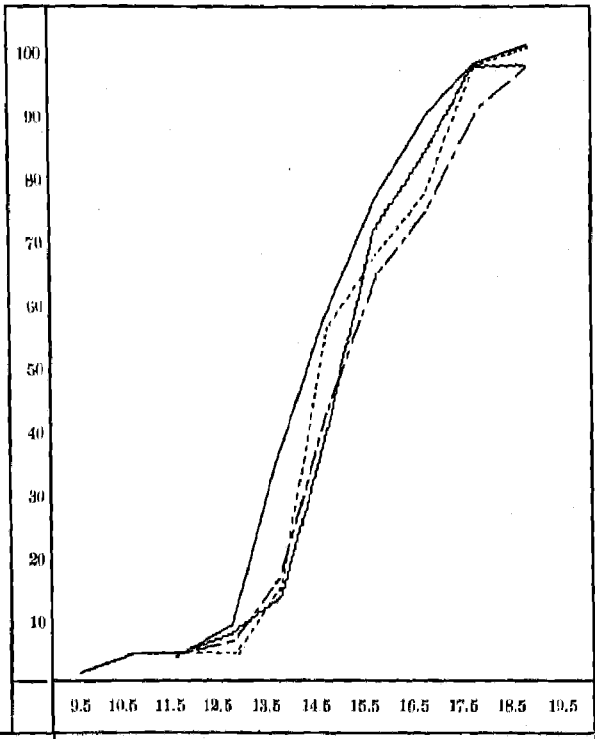
*NOTE. *The following data are taken mainly from "Adolescence," G. Stanley Hall.*

CHART I.

PHYSIOLOGICAL AGE. VARIOUS OBJECTIVE SIGNS.

[GIRLS.] ITALIAN.

Plotted from data from *La Puberté*, *Marro*.



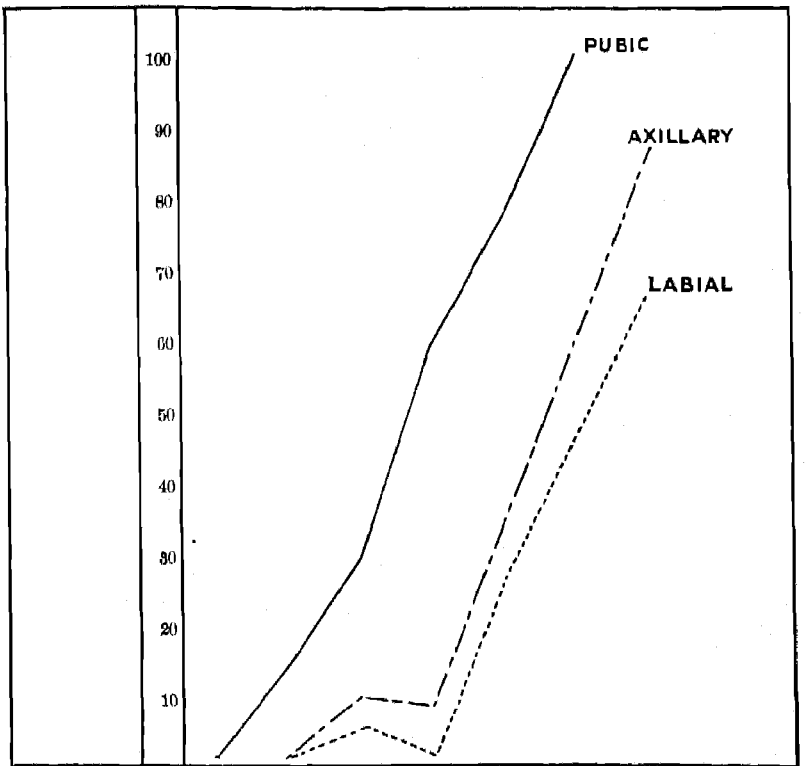
	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	
Pubic Pub.....	0	3	3	9	35	57	76	89	90	100		———
Axillary Pub.....	0	3	3	6	16	42	64	74	90	96	— ?	- - —— -
Menstruation....	0	3	3	3	15	55	07	77	96	100		.....
Dev. of Breasts..	0	3	3	7	13	40	71	89	96	96	— ?	~~~~~

CHART II.

PHYSIOLOGICAL AGE. PUBESCENCE.

[BOYS.] ITALIAN.

[PUBIC, AXILLARY, LABIAL.]

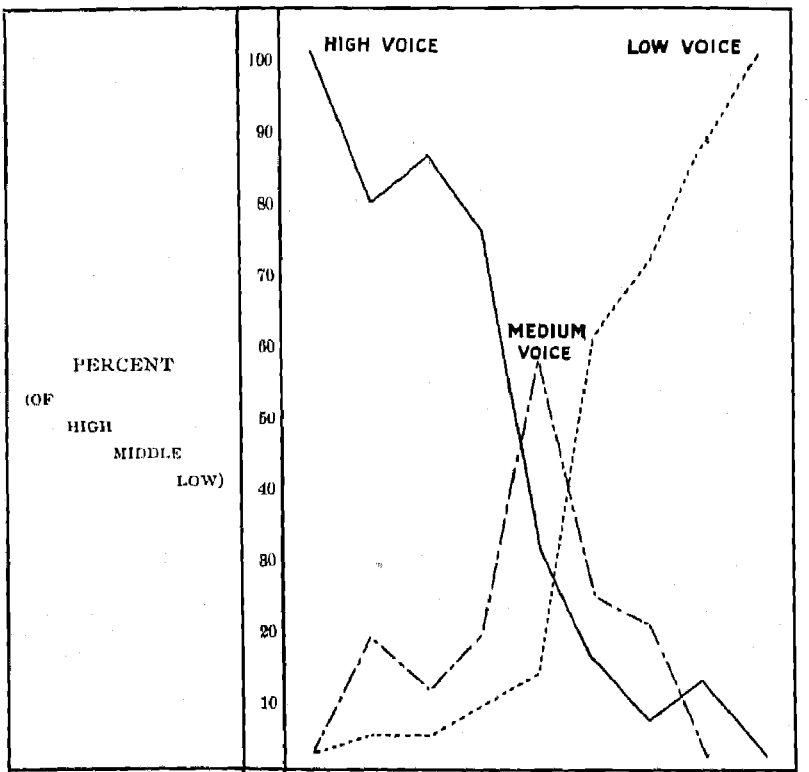


Age	Yrs	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5
Pubic	%	0	14	29	59	77	100	100	
Axillary	%	0	0	11	9	38	57	88	(50)
Labial.....	%	0	0	4	0	26	43	66	(50)

OBS.—Pubic pubescence corresponds closely to American observations. Irregularity probably due to insufficient data. Percentages calculated from tables given by *Marro*. Italian observations.

CHART III.

PHYSIOLOGICAL AGE. CHANGE OF VOICE.



Age		11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5
High Voice.....	%	100	79	86	74	30	16	7	12	0
Medium Voice.....	%	0	18	10	18	57	23	21	0	0
Low Voice.....	%	0	3	3	7	13	60	71	87	100

OBS.—Irregularity in curves is due to lack of a large number of cases. Plotted from table by *Marro.*

period. All the internal organs grow rapidly at this time; the kidneys and the liver seem to grow very slowly afterward.

The salivary and the sebaceous glands increase markedly in size and function at this period. Acne and comedones are characteristic. Pigmentation of all colored structures increases, the sexual organs and nipples with their areola become darker.

Boys lose fat, girls often grow thin but soon round out. Stratz classifies his physiological ages on this basis. He schedules "erste Fülle," "erste Strechung," "zweite Fülle," "zweite Strechung," and finally "die Reifung." The transition from the "zweite Strechung," to "die Reifung" possibly corresponds to puberty.

My own observations, confirmed by my assistants, tend to substantiate this. A pre-pubescent has flesh of a tallowy feeling, and his cheeks are rounded, the post-pubescent seems dried out. The skin is not so closely attached to the subcutaneous fat and seems more compact.

Right-handedness and asymmetries occur and become accentuated; right-handedness and scholarship are correlated, according to Smedley.

Hall says: "Puberty is like a new birth. It is the age of reconstruction when new determinants come to the front, and also the point of departure for new development.

"It is the age, too, when, if ever, previous tendencies to abnormality may be overcome both by nature and by treatment. The law of nascent periods or the age curve of growth of each organ or faculty, is one of the first desiderata of genetic psychology; how to apply it, by what means and to what degree to stimulate each part in its stage of most and least rapid growth, and how to apportion training of mind and body - is one of the chief problems of individual pedagogy."

Turning to diseases which are characteristic of the ages of puberty, we find a rich field. Childhood diseases decrease, while rheumatism, disorders of bones, muscles, circulation, etc., increase. Goitre, anaemia, hysteria, epilepsy and a special form of chorea, are stated to be characteristic diseases. "Growing pains" and minor attacks of rheumatism are frequent. It is stated by many authors that the morbidity of the pubescent age is high, while the mortality is low.

Nervous disorders, particularly chorea and stuttering, become marked. Appetite changes, becomes more fastidious, and shows many anomalies.

Functional heart troubles, shortness of breath, palpitation, dyspnoea, languor, feeble pulse and cardiac discomfort, irritability, inertia, sleeplessness, are all cardiac symptoms of the

pubescent period. Chlorosis and anaemia are notoriously characteristic, and nosebleed is a common symptom.

On the mental side we have a peculiar tendency to morbidity. The birth of the sexual impulse normally causes an upheaval of the whole mental life. Masturbation and other abuses assist in unhinging the weak mind. There are numberless forms of trouble taking their origin at this point. From simple day dreaming to the gravest forms of dementia precox there is a series with countless numbers. Irregularities in conduct, obsessions, cravings, wilfulness, hysteria in all its forms (particularly religious), phobias, blind impulses, sexual perversions are characteristic. It is probable that by far the largest portion of our insane cases begin their trouble at or about this time.

In view of the important features of the period of life under consideration it is particularly important that the study of these features should be adjusted as to developmental periods in contra distinction to age groups.

SECTION I

PHYSIOLOGICAL AGE AND PUBESCENCE DELINEATED

The present investigation was undertaken in the spring of 1901. The problem that arrested my attention at that time was the great and unexplained variability of boys of the high school ages. There were undoubtedly reasons why one boy of 14 years of age was small and another large; one tall and thin, another short; one weak, another strong; one brilliant, another dull.

A series of measurements was undertaken for the purpose of comparing certain physical features of boys who had proved failures in their studies with those who had proved brilliant. This was pursued for a year with the result that no correlation appeared. While taking the records the writer noted that some boys were distinctly pubescent (as to the pubis) while others of the same age were not. This led to the record of this feature, and the findings point to the fact that the whole attitude in respect to the boy at or about the age of puberty must be radically changed. Hitherto there has been no record of the maturity or immaturity of a boy at "the age of puberty." He has been classed "at the age of puberty" regardless of whether there might be years before he would arrive at puberty, or whether he had arrived there years before. There has not hitherto been made a distinction where there is a profound difference. It is almost incredible that we have been so dilatory in this respect; while literature abounds with evidence of the

general growth rates of boys at the age of puberty, the writer has searched in vain for any data concerning the differential characteristics of the pre-pubescent as distinguished from the post-pubescent.

It is my firm conviction founded upon the evidence herein presented, that all our observations of the young adolescent, whether anthropological, medical, educational, or social must rest upon this definite classification, and not upon indefinite age designations. The attempt to establish an age - in the child labor movement - above which a child may safely work and under which he may not, may well take this fundamental fact into consideration.

It will be my purpose to set forth in this paper the relations of one of the phenomena of puberty with age, growth and growth rates, scholarship, etc., entirely rearranging the data personally obtained upon the basis of signs of puberty, and contrasting these data with those related to the age basis; thereby hoping to demonstrate the need of a complete revolution in our methods of observing and treating the growing boy.

Puberty

Puberty is usually the criterion of designation of one of the periods in almost every one of the multitude of classifications; it is probably the most interesting landmark in all life, for it is the point about which are grouped the most significant and peculiar phenomena of life. Accelerations and retardations in growth rates, asymmetries and anomalies in structure, the disappearance of old, and the budding of new faculties and functions, together with the greatest and most fundamental of all, the change from an asexual to a sexual life, all make puberty worthy of extended and exact study.

Definitions

On account of the general misuse of terms relating to this period, it is well to submit the following definitions:

"Puberty" from pubertas-tatis ("age of manhood") refers to that point of time when the asexual life is changed to the sexual, and the ability to procreate is established. It is not a stage or period of time, but a division line between two periods having no more duration than the division between one year and the next.

From the nature of the case it is practically impossible to determine this moment with exactness. Experimentation is almost wholly precluded. It is only by external and objective signs that we know that puberty is approaching; is about here;

or is past. All references to the "age of puberty" are inexact in this sense, and the term is far more misleading when it is applied in a general way to any one year which may or may not be indefinitely the average age of puberty.

"Adolescence" from adolesco-ere, evi, adultum, (the "period of ripening") extends from puberty to maturity, and is generally considered to be in the male from 14 to 25 years of age - in the female from 12 to 21. The root verb is an inceptive or incohative and as such signifies a continued act or process. Hence adolescence is a period of time in which certain events may take place in contradistinction to puberty which is the moment of beginning adolescence. Adolescence begins at puberty and ends with maturity.

"Pubescence" from the incohative pubesco, ere, evi again denotes a process covering a period of time, the completion of which is often vaguely understood to be puberty. This is a term which is often loosely used to denote puberty, or adolescence. It should be used to mean the process of becoming covered with hair, and unless qualified should have reference to the pubic pubescence alone. A pubescent is an individual who is undergoing this process and is in the period of pubescence. The period of pre-pubescence begins at birth and ends at the beginning of pubescence and all in this period are pre-pubescents. All those who have completed their pubescence are post-pubescents. The transition from the pre-pubescent stage to the pubescent stage is gradual. It is begun by an evident and rapid growth of the fine hair apparently already present. This is readily distinguishable, and this characteristic marks the first part of the period of pubescence; the second period of pubescence commences with the pigmentation of this exaggerated growth and pubescence arbitrarily ends with the appearance of the kink or twist which is definitely characteristic.

This classification of the features of pubescence is, so far as I know, original, at least in its present form. It forms the foundation of this thesis, and will become, it is hoped, the basis upon which all facts referring to pubescence and puberty will be definitely related from this time onward. It is a definite classification and meets the requisition of science - that facts of observation must be of such a nature as to be corroborated by other observers.

There is a very small percentage of error in observation. The three assistants now carrying on this work (the only ones making these observations within the knowledge of the writer) have tallied respectively less than one per cent of variation from each other and from the writer. This shows the classification more definite and less liable to error than estimations

of eye color or complexion records which were taken at the same time.

PUBESCENCE AS A CHARACTER

It is important that the correlation of age and the pubescence characteristics be stated at the outset. It will be seen that there is a great range of year variation.

Percentage of Pre-Pubescents for Each Half Year

TABLE I.

3835 RECORDS FROM NEW YORK CITY HIGH SCHOOL BOYS.

Age	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75
Per Cent.	(81)	69	53	41	26	16	9	5	2	1	0	0

From this it will be seen, for example, that as many as 19 per cent of all high school students in the first half of the thirteenth year (the 12.25 group) have left this class of immaturity and it is not until the eighteenth year that all have begun their pubescence. Each half year group save the extreme years of the series shows that its population consists of at least two classes, the pre-pubescents and all others.

The data upon which this paper is based, and all figures given, are from records taken by the writer, or under his immediate direction, from New York City high school boys during the years 1901-1906. The actual percentages, averages, etc., apply to this class of boys only, and probably to this one group alone, for it is hardly possible that this group is exactly duplicated elsewhere. The racial, social and other factors will vary infinitely. The principles laid down from the study of these data are, however, universally applicable.

Data are herein arranged in half year groups, the central point of the half year is used to designate the group. The above and other tables include subsequent measurements of the same individual and should be regarded in that light. In view of the fact that half year groups are used instead of year groups it has not seemed advisable to enter into the labor of calculating the exact average of the ages of all individuals in each half year group as has been advocated by Smedley. (46th Annual Report Board of Education, Chicago.)

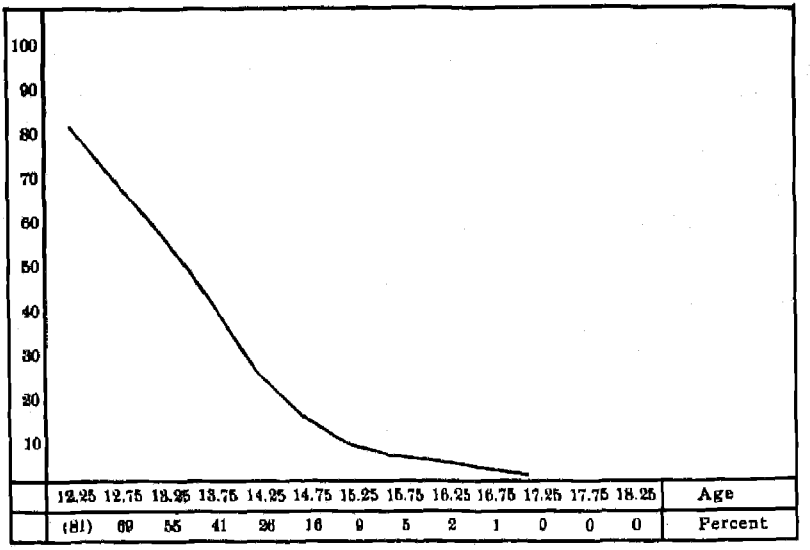
The rapidity of this change from the immature group, which we may call the pre-pubescents, is shown well by the steepness of the curve of Chart I, and Table II giving decrease in per cent between each one-half year. The figures under each age are the

decrease between that age and the next.

CHART I.

PERCENT OF PRE-PUBESCENTS FOR EACH HALF YEAR.

High School Boys, N. Y. C. (3835 Cases.)



OBS.—This chart shows the rate of disappearance of the immature group.

TABLE II.

Age	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75
Per Cent.	12	14	14	15	10	7	4	3	1	1

The change is most rapid from 13.75 to 14.25. Hence, this is the height of the curve of frequency of beginning pubescence. The other ages immediately preceding this, however, are also popular, and the average date is much earlier than the mean date. For the ending of pre-pubescence and the beginning of pubescence the middle of the mean year is 14.00 years, the average date is 13.44 years with a variability of $\pm$ 1.51 years as expressed by the standard deviation. This calculation takes into account the theoretical distribution of the earlier years.

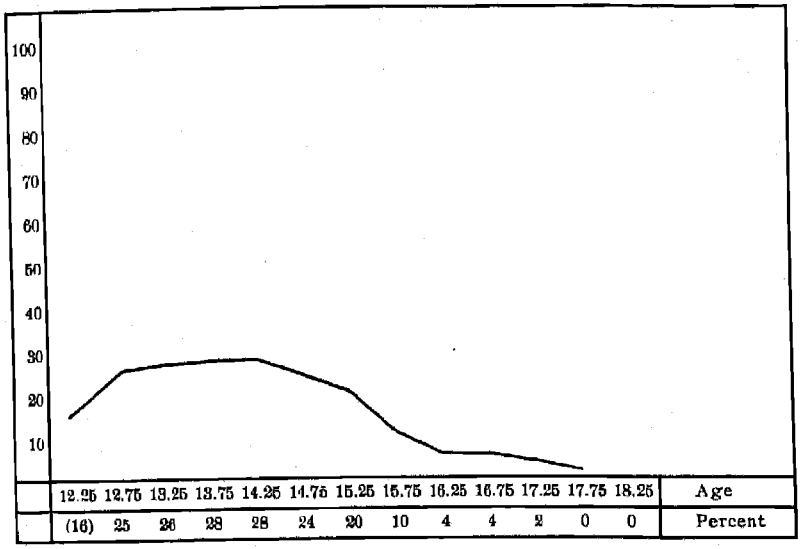
It is hoped that not too much importance will be attached to

the average ages of any feature of pubescence, although they may be useful as an incomplete basis for comparison of different racial and social groups. They do not give any information of the characteristics of the population of the age group, which are of prime importance.

CHART II.

PER CENT OF PUBESCENTS FOR EACH HALF YEAR.

High School Boys, N. Y. C. (3835 Cases.)



OBS.—This chart shows the maximum and disappearance of the Pubescent group.

TABLE III.

PERCENTAGE OF PUBESCENTS FOR EACH HALF YEAR.

Age	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75	18.25
Per Cent.	0	25	26	28	28	24	20	10	4	4	2	0	0

See Chart II.

It appears from this table that there are six half years, from 12.5 to 15.5 in which there are 20 per cent or more of the population who are in the stage of pubescence. In no one half year is the per cent of pubescents over 30 per cent. Therefore it is not fair to give to any one year the designation "the year of pubescence" for at any age the large majority are not pubescents.

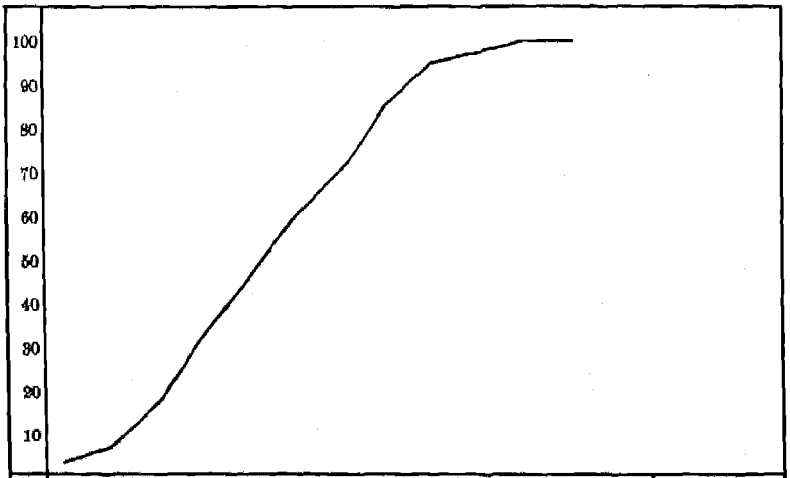
From 13.5 to 14.5, however, our figures show the greatest percentage of any time, and it is evident that this year is the middle of the three in which pubescence usually takes place.

We may treat this table of percentages as frequencies and calculate the middle point. This is 13.90 years with a variability of $\pm$ 1.11 years. This age is the middle age of the population of pubescents.

CHART III.

PER CENT OF POST-PUBESCENTS FOR EACH HALF YEAR.

High School Boys, N. Y. C. (9835 Cases.)



	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75	18.25	Age
	(2)	6	18	31	46	60	70	85	93	95	98	100	100	Percent

OBS.—This chart shows the rate of increase of the mature group.
[Per cent at 12.25 estimated.]

TABLE IV.

PERCENTAGE OF POST-PUBESCENTS FOR EACH HALF YEAR.

Age	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75
Per Cent.	6	18	31	46	60	70	85	93	95	98	100

See Chart III.

The increase in percentage from one-half year to the next is shown on Table V, whereon the rate of increase of the post-pubescent group is given. The difference between each half year and the next is given under the first half year.

TABLE V.

Year	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75
Per Cent. Increase	6	12	19	15	14	10	15	8	2	3	2	0

The increment is largest at 13.75 to 14.25 and 15.25 to 15.75. There appears to be a distinct lull at 14.75 to 15.25 which makes the frequency curve bimodal. The younger group is far more extensive, ranging from 12.75 to 14.25, while the mode of the older group at 15.25 is isolated. The average value of this transition from pubescence to post-pubescence is 14.50 years and the variability 1.21 years.

This is as near as we can get to the average age of puberty by this, the so-called generalizing, method (viz. comparing age groups); later, by the study of individuals as such, we can arrive at the same end by a more direct means. This date will be different in every group studied. In Germany it will be nearly a year later, in Norway probably more. If we take a group of children whose parents belong to the upper middle class, the date will be early, in the lower class it will be late. The group studied is 98 per cent American born, but in about 40 per cent both parents were born abroad.

Summary of Percentages

For the sake of clearness, the percentage composition of the age groups studied is assembled and given in Table VI.

TABLE VI.

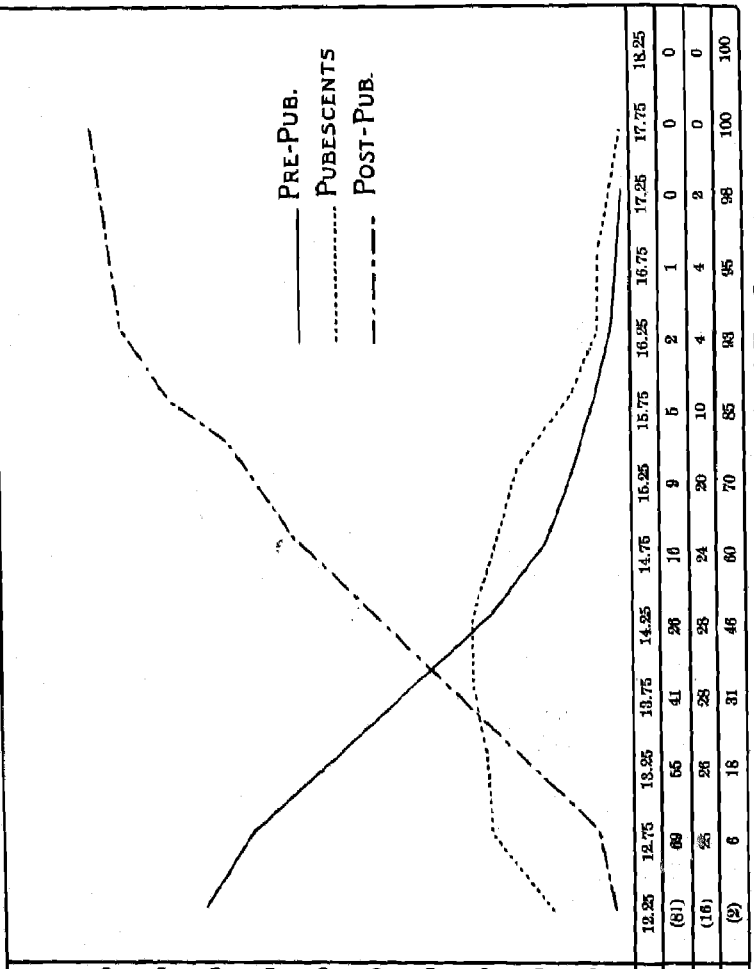
Half Year Age Mean	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75
Per Cent. in I.	(81)	69	55	41	26	16	0	5	2	1	0	0
" " II.	(16)	25	26	28	28	24	20	10	4	4	2	0
" " III.	(2)	6	18	31	46	60	70	85	93	95	98	100

Physiological Age of Pre-Pubescents

We have catalogued the pubescence characteristic of each age group and determined that there is a certain percentage of each pubescence group at each age. The rate of reduction of the immature class has been shown up to the point of its disappearance, but before leaving the subject it is possible to calculate one more important fact concerning the groups.

Referring to the age group 12.75 (12.50 to 12.99), for example, we see that 69 per cent of all are pre-pubescents and that these are destined to become pubescents at varying periods afterward. There is no sign now known by which we can pick

CHART IV.



Age Group	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75	18.25
Pre-Pub %	(81)	69	65	41	26	16	9	5	2	1	0	0	0
Pubescents %	(16)	25	26	28	23	24	20	10	4	4	2	0	0
Post-Pub %	(3)	6	10	31	46	60	70	85	93	95	98	100	100

Percentage of each Pubescence Sub Group for each Half Year Group.

out of this group the individuals who are on the verge of pubescence as distinguished from those who will remain several years immature; although we know that 14 of this 69 per cent will change within the next half year and that one per cent will require four years.

This 69 per cent, however, will change at the following rate:

TABLE VII.

Years	
0.0 to .5	14
0.5 to 1.0	14
1.0 to 1.5	15
1.5 to 2.0	10
2.0 to 2.5	7
2.5 to 3.0	4
3.0 to 3.5	3
3.5 to 4.0	1
4.0 to 4.5	1
	69

From this it appears how variable this population really is. Although they are pre-pubescents, some are much younger physiologically than others. For this group of pre-pubescents the average time that will elapse before pubescence is 1.37 years $\pm$ 1.13, while the extreme range is from 0 to 4.5 years. This fact should be borne in mind when any group of pre-pubescents is considered.

In a similar way alternate half years have been calculated as to the average and variability of the duration of pre-pubescence, and the results are given in Table VIII.

TABLE VIII.

AVERAGE EXPECTED DURATION OF PRE-PUBESCENCE.

Half Year Age Group	Years of Average Expectancy	Variability.
11.75	1.88	$\pm$ 1.16
12.75	1.37	1.13
13.75	.97	.77
14.75	.78	.59
15.75	.55	.40

The high school series does not contain any individuals below 12 years. The curve of frequency below this point has been calculated upon the basis of the nature of the rest of the curve. There are thus 93 per cent pre-pubescents at 11.25 (theoretically).

Attention may be called to the table of variabilities. These express the homogeneity of these sub-groups. This is a feature of great importance, for we would expect to find that all char-

acters which are highly correlated with pubescence would show a similar variability. This variability is a means, although somewhat restricted in function, by which we may explore indirectly for signs of approaching pubescence.

Physiological Age of Post-Pubescents

We may use a similar line of analysis for the post-pubescent group and find out for each age how old they really are in terms of the years elapsing since their entrance into the post-pubescent group. However necessary this may be for determining the characters of a group, it is unnecessary for the individual case, if we have the recorded history of his pubescence. This as yet we seldom have, and it is especially true in our everyday practice, where we meet an individual for the first time. It is to be hoped that the future will correct this, and that all schools will have accurate records for all children under their care.

Another possible method is the observation of the amount of pubic pilosity, the appearance of axillary tufts, hair on the upper lip, etc., although none of these tally with any special date after pubescence.

Taking the half year 17.75, the first half year in which the total observed population is post-pubescent, we find that these 100 per cent have arrived at this stage in accordance with the following table:

TABLE IX.

Time Elapsed Since Puberty Years	Per Cent. Units
0.0 to .5	2
0.5 to 1.0	3
1.0 to 1.5	2
1.5 to 2.0	8
2.0 to 2.5	15
2.5 to 3.0	10
3.0 to 3.5	14
3.5 to 4.0	15
4.0 to 4.5	13
4.5 to 5.0	13
*5.0 to 5.5	3
5.5 to 6.0	2
6.0 to 6.5	1
	100

This table shows the exact constituency of the post-pubescent group at 17.75 and demonstrates the high degree of variability. Similar calculations have been made for each alternate half year age from 13.75 to this 17.75. The average and

*NOTE. The figures given for five years and over are theoretical.

the variability are given below in tabular form:

TABLE X.

Half Year Age Group	Average Post-pubescent Value—Years	Variability
17.75	3.23	± 1.25
16.75	2.43	1.12
15.75	1.63	.98
14.75	1.13	.72
13.75	.70	.61

This table shows the post-pubescent value of each of the half years given and its variability. On account of the greater variability at the later years, we would expect a greater variability in these groups of all characteristics allied with pubescence. This deduction is borne out by the facts given later in the analysis of the weight-height correlations of pubescence.

"Percentage of Pubescence" at Various Ages

It will assist in clearness if we can designate each age group with a percentage of pubescence. In computing this, the pre-pubescent per cent units are given the value zero, the pubescent one-half, and the post-pubescent one. This gives the pubescents a hypothetical weight and influence of one half the post-pubescents. Where all are pre-pubescents, as for instance at the age of 4 years, the percentage would be zero. Where all are post-pubescents, as at the age of 25 years, the percentage would be 100. The limits of this scale are zero and 100. The group under observation gives the following percentages:

TABLE XI.

Age Mean	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75
Pubescence Percentage	(10.0)	18.5	31.9	44.9	59.8	71.6	80.4	89.6	95.3	97.0	99.1	100

By the use of this table we can compare other groups with this standard, and internal sub-groups can be segregated and compared. Even if we have sufficient data in only one year, we can gauge our results on this basis and determine retardation or acceleration of pubescence for the group. In this way we can study the correlation with nationality, social status, complexion, truancy, child labor, weight, strength, scholarship, etc., using any natural or artificial method of forming groups.

It is needless to say that the writer has not had the opportunity to go far into these by-products of the main investigation during the five years spent in elaborating this study. Other and more direct means have been taken to study weight, height,

strength, and scholarship. During a period of "exploration," however, the writer took records of some 300 high school children of American born parents and compared them with a similar series of children of German parentage, though American born. The results are given in Table XII (see next page).

This shows conclusively that the American born children of German parents are later in their development, a fact that explains a great many features of growth in which this group differs from others. These features are secondary to and dependent upon pubescence, and vary with it. When we have determined the pubescence characteristics of a group, we have largely determined all the accessory features dependent upon it. These facts will become apparent as we proceed.

Summary and Conclusions

The foregoing argument is a study of a sexual characteristic, its appearance, its stages and its final term of completion. This character has sufficient definite objectivity to be used by any one of ordinary powers of observation. It is feasible and reliable. It is an indication of progress from the asexual to the sexual, and the progress from the stage of pubescence to that of post-pubescence marks the dawn of the ability to procreate.*

The rate of decrease of the immature class, the rise and fall of the transition group, and the rapidity of increase of the mature group have been catalogued.

All of these "pubescent ages" contain a mixed population, and emphasis has been laid upon the fact that it is impossible to predicate from the mere fact of age (from 12 to 17 years)

*NOTE. *As this statement has a serious medico-legal significance, it is well to state that the evidence upon which it is based rests upon a microscopical examination of the secretion of several cases. These cases came to my notice from an entirely unsolicited source, and occurred in practice, and not in the course of this investigation. I believe that wholesale experiment on this point is to be deprecated. In every case well formed and mobile spermatazoa made their appearance in the months of transition to post-pubescence. This correlation of pubescence and actual puberty rests upon these observations, and the conclusion of coincidence of puberty and the ending of pubescence is warranted. Throughout this thesis this point will not be obtruded; nor is it necessary, for all references will be made to pubescence stages, which are purely objective and admit of absolutely no error. All references to puberty in the male, at least, are inexact unless based upon actual observation or upon the definite relation to pubescence.*

TABLE XII.

NATIONALITY AND PUBESCENCE.

Parents Born in the United States.

Age—Year—Mean	13.5	14.5	15.5
Pubescent Stage I.	50%	21%	8%
" " II.	33%	36%	22%
" " III.	17%	42%	69%
Pubescence Percentage	83.5	60.	80.

Parents Born in Germany.

Age—Year—Mean	13.5	14.5	15.5
Pubescent Stage I.	59%	36%	28%
" " II.	29%	30%	24%
" " III.	12%	33%	46%
Pubescence Percentage	26.5	48.	60.

that an individual is immature, maturing, mature; when he will mature, or how long he has been mature, All designations of sexual characteristics based on age alone are incomplete and misleading.

The variability of the appearance of these characters is great. The total normal range of pubescence, for instance, is about 8 1/2 years and the variability (sigma) is 1 1/2 years. This is so great that we cannot predicate, with even a fair degree of accuracy, the one feature from the other.

The expectancy of pubescence for each year, and the degree of post-pubescence have been calculated. These give definite information as to the characteristics of these pubescent half year sub-groups.

An empirical pubescence percentage for each half year has been set forth, and as an example, the values for children of German and of American parentage have been compared.

SECTION II

THE SIGNIFICANCE OF PHYSIOLOGICAL AGE IN TERMS OF STRUCTURE AND FUNCTION

Various physical measurements of high school boys have been taken, and the pubescence sub-groups for each age have been segregated and serve as bases of mutual comparison. These are weight, height, strength, and scholarship, and will be taken up in that order.

Pubescence and Weight

The weight of each boy was taken (without clothes) and the results are given in Chart V.

CHART V.

WEIGHT AND PUBESCENCE.

	Age.	12.25			12.75			13.25			13.75			14.25		
	Pub. Stage	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
WEIGHT IN KILOS.	20-24							1				1				
	25-29	2			1			10	1		11	3	1	17	5	
	30-34	4			11	4		44	13	2	73	22	7	54	25	8
	35-39				13	5		45	22	6	57	39	20	46	59	44
	40-44				1	2	1	12	10	12	20	21	30	22	27	68
	45-49						0		1	5	3	8	24		13	52
	50-54						1			3		1	9		2	27
	55-59						1			2			4		0	13
	60-64									1			1		0	6
	65-69												1		1	3
	70-74															0
	75-79															1
	80-84															
	85-89															
	Number.	6	0	0	26	11	3	112	47	31	164	94	97	139	132	222
	Average.				35.19	36.59	(50.9)	35.04	37.18	44.27	35.40	37.95	43.94	36.19	39.03	45.45
	Sigma.				5.17			4.17	4.04	7.08	4.27	5.20	6.94	4.49	5.67	7.47

	Age.	14.75			15.25			15.75			16.25			16.75		
	Pub. Stage	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
WEIGHT IN KILOS.	20-24															
	25-29	6	3		1	1	3	1	1	1						
	30-34	25	28	8	11	17	9	8	6	4	1	1	1		1	1
	35-39	40	53	46	22	45	32	7	11	22	1	3	7		1	0
	40-44	11	29	62	7	18	65	2	7	55	1	2	21	1	1	9
	45-49	2	9	76	5	6	70	1	9	78	1		34		2	29
	50-54	3	3	57		4	61	1	2	62			46			25
	55-59		1	19			31		0	40			31			22
	60-64		0	6			13		1	14			13			13
	65-69		1	4			3			4			1			2
	70-74			4			0			2			0			1
	75-79			2			1			0			1			0
	80-84									0			0			0
	85-89									1			1			2
	Number.	87	125	284	46	91	288	20	37	283	4	6	156	1	5	104
	Average.	36.76	38.86	47.81	37.09	38.78	47.70	36.75	41.29	49.91	(40.)	(38.32)	51.65	(42.5)	(41.5)	53.51
	Sigma.	5.17	5.88	8.07	4.75	5.06	7.81	5.78	7.11	7.78			7.67			8.84

	Age.	17.25		17.75	18.25	18.75
	Pub. Stage	2	3	3	3	3
WEIGHT IN KILOS.	20-24					
	25-29					
	30-34	1				
	35-39	0				
	40-44	1	5	1		1
	45-49		15	3	1	0
	50-54		7	8	1	1
	55-59		12	4	1	0
	60-64		10	2	2	2
	65-69		4	5	1	1
	70-74					0
	75-79					0
	80-84					1
	85-89		1			
	Number.	2	54	23	6	6
	Average.	(37.5)	54.08	58.41		
	Sigma.		8.59			

Explanation of Chart. The half year groups include from 12 years and no months up to but not including 12 years 6 months. Pre-pubescence is denominated first stage, pubescence second stage, post-pubescence third stage. These designations will be used hereafter. The numbers given on the chart are the "frequencies" viz., the number of individuals who belong in the age group, pubescence group and weight group designated; thus three characters are considered. Below the number of records in each age pubescence group is its average and its standard deviation.

Observations

(1) From mere inspection it is evident that the total range of each sub-group within a single age does not coincide. At the age group 13.0 to 13.5, group one ranges from 22.5 to 42.5 kilos. Group two from 27.5 to 47.5; group three from 32.5 to 62.5.

(2) The averages for each group show a considerable difference. This difference averages about 10 kilos between group one and group three at each age. This and the foregoing point are proof positive of the utility of the method of sub-grouping, for they both point the fact that the sub-groups have essentially different weight values.

(3) It will be noted that in the whole series there are no pre-pubescents above 55 kilos in weight, and only 4 that are in the 52.5 kilos class, while there are 254 post-pubescents below 16 years who are above 55 kilos in weight. In the 14.25 group there are no pre-pubescents above 45 kilos, while there are 46 per cent of the post-pubescents above that point. Similarly in the same group there are no post-pubescents below 30 kilos in weight, while there are 12 per cent of the pre-pubescents below that point.

(4) At the age 15.75 the post-pubescents are 34 per cent heavier than the pre-pubescents. This is typical and not exceptional.

(5) For the sake of greater accuracy the table above shows measurements grouped in half year groups; but the averages for three whole year groups have been worked out, and are presented below with their standard deviations:

	Physiological Age.				
Age in Years.	1	2	3	All.	Sigma.
13	34.9	37.7	43.9	37.9	6.26
14	35.7	38.7	46.3	42.	8.19
15	37.5	39.5	48.5	46.5	8.39

(6) It will be noted from this table that the differences

between the groups one and three at each age are about equal to the difference between the averages (of all) for the years 13 and 15. That is to say, the difference of these groups is about the same as the difference of two years by the old method of grouping.

(7) The difference between the thirteenth year and the fourteenth year pre-pubescents is about 0.8 kilos, while the difference between the first and third group of the age 13 is 9 kilos, or about eleven times as great. From this it is evident that the difference between these two groups of the same age is far greater than the difference between two similar pubescence sub-groups which have a year's difference in age. The pubescence grouping is far "stronger" than the age grouping.

(8) The standard deviation or sigma of each group is given. The sigma is an indication of the variability of the group, and gives to a great extent an idea of its homogeneity. It will be noted that the sigmas of sixteen out of the eighteen sub-groups of the three years 13, 14, 15 are less than the sigma of the including year group, despite the fact that the number of the individuals in each group is smaller, which would naturally cause a greater sigma.

The sigma of the post-pubescent group in each case is much greater than that of the pubescent or pre-pubescent groups. This accords with the findings of our discussion in Section I, where it was shown that the variability of the post-pubescent groups, as to their number of years since pubescence, was considerable, causing this group to be highly variable as to post-pubescence value. The variability of post-pubescence, and the variability of weight of this group move in the same direction and are correlated. This is a secondary proof of the correlation of weight and pubescence shown by the relation to the averages of the pubescent sub-groups. It also leads us to the presumption that the years immediately succeeding pubescence have a high weight growth rate. Actual data on this point will bear out this presumption.

(9) We can infer from this table something as to the character of the growth rates of weight. It will be observed that there is but a small, though constant difference between stage one and two. This would lead us to believe that there is a similar increase in weight in the passage from stage one to stage two. There is uniformly a greater difference between two and three. The average relation of these differences is about as three is to seven. This leads us to presume that growth in weight is more than twice as rapid as that associated with the change from one to two. The actual facts gleaned from the individual treatment of the records of successive measurements

bears out this presumption, and the results will be given in the discussion on growth rates.

(10) A method of interpolation or assigning age values to weights has been instinctively and erroneously used by the medical profession as well as the laity. A boy's weight is noted, and the scale of average weights is called into play, and on this basis the boy is assigned a certain age value. He is stated to be at the appropriate weight for a certain age. If this age is below that of his own years, he is said to be below weight, and a correspondingly unfavorable impression is registered; if he weighs as much as the average of an older group he is to be correspondingly congratulated. This is somewhat fallacious, for it does not take into consideration pubescence classes. A boy of 13 years may be a heavy pre-pubescent and yet fall below the average of his year, and similarly a boy may be low in the scale of post-pubescents and yet be above the average of his year.

Let us examine the data of one year and show the year values of the three sub-groups, basing the calculation upon the average of the total population for each year:

TABLE XIII.

WEIGHTS OF SUB-CLASSES AND CORRESPONDING YEAR VALUES—AGE GROUP 14.75.

	Weight.	Years Age Value.
Pre-pubescents	36.76	12.75
Pubescents	38.86	13.77
Post-pubescents	47.21	15.69

Thus the instinctive method of classification of children on the weight basis is subject to a variation of nearly three years.

Results

Individuals differ from each other in weight according to their maturity. This with similar statements concerning height, strength, etc., is the main thesis, and can be stated in various ways. Each age group of any year from 11 to 18 contains a population that varies in a fundamental characteristic, causing the individual to fall into sub-groups which differ from each other far more than do contiguous age groups. The most important record that we can make of individuals of this epoch is not the age, but the fact of pubescence or non-pubescence, for the physiological age so expressed is far more significant.

In making any observation on the child, we cannot afford to be ignorant of the fundamental feature. The whole of our education has been ignorant of this point for it regards but age in

years alone. The whole of our medication, in so far as it applies to this period, has never had this scientific foundation; our social organization of this group, in so far as an endeavor has been made by adults to meddle with the automatic self-adjustment of these individuals, has been bungling and inefficient. Where natural groups have been allowed to establish themselves, they remain natural and coherent; where an age basis has been interjected as a means of classification, the result has been chaos.

The whole endeavor of those who are interested in preventing the evils of child labor has been astray up to the present point for the reasons given above. There is no one age when the child is mature enough to work. There is, however, a point of time after pubescence when the growth accelerations are over and cannot be interfered with, that marks the time when the child may undergo the strain of labor with less disastrous results. This may well form the basis of practical legislation which the unscientific age basis alone, cannot.

The Correlation of Height and Pubescence

Height and weight are somewhat related to each other. One is the linear measurement of a thing, while the other is a function of a cubic measurement.

Records of height have been taken from practically the same series of students as were used for weight records. The results are given in Chart VI.

Explanation. These data were first grouped in 5 cm. groups. This was deemed insufficient in definition, and the records were rearranged in 2 cm. groups which are perhaps unnecessarily small, though they are conducive to accuracy. As it was early seen that the number of years after pubescence would affect the group values, it was determined to segregate those individuals who were recorded for the first time as post-pubescents. These are tabulated under 3^1, all others are put under $3\underline{x}$. There are, of course, some in this class ($3\underline{x}$) whose records were taken for the first time, and it is unknown whether they were in the first half year of post-pubescence or not. The average and its sigma have been worked out for 3^1 alone and for 3^1 and $3\underline{x}$ combined, not $3\underline{x}$ alone for this reason. With the increase of data in the future we will expect to be able to present values for 3^1, 3^2, 3^3, etc., corresponding to the half years past pubescence. At present this is impossible.

The deductions which can be drawn from this work are similar to those drawn from the work on weight. The range of distribution, values, averages, the comparison and flow of the standard deviations all follow the same course, and it is un-

CHART VI.

HEIGHT AND PUBESCENCE.

necessary to repeat this line of analysis.

The integrity of the sub-groups and their method of grouping is substantiated and is represented with striking clearness. The actual distribution is frankly given in full so that any investigator may verify the results and use the data for further or different methods of analysis.

As there are several terms' records included in this chart, and pubescence varies as to term, it is advisable to state the term characteristic of the population below:

TABLE XIV.

1st Term.....	2152
2d "	953
3d "	490
4th "	169
5th "	55
Total.....	3819

Correlation of Strength and Pubescence

A similar series of records were made of strength of grip of the right hand. This is a peculiarly appropriate test of strength, for according to G. Stanley Hall it has a significance related to the efficiency of the individual in meeting the conditions of arboreal life. Moreover, it follows closely the function of other muscular groups notably of the back and legs, and of "chinning" ability. The two bar dynamometer of the Narraganset Machine Company was used. While the value of the Smedley form is recognized, comparative tests made by me show a smaller variability between the two machines than between successive tests on one individual, hence the usual type was employed chiefly on account of its convenience and durability.

The variability of this test is far greater than either of the others. This is to be expected as it is a test of function and not of structure. Despite this fact, the variabilities are not as high as would be expected under the circumstances.

From an inspection of Chart VII it will be seen that there is a general coincidence with our findings on weight and height. This proves the validity of our sub-grouping upon a basis of function as well as structure.

It is unnecessary to enter upon a detailed discussion of the importance of the various features of these results. A similar line of analysis to that used upon the weight and height results may be employed.

There is but one important difference, however, and that is the fact that at the ages of 15.75 and 16.25 the pubescents are

Chart VII.

Strength and Pubescence.

Year 12

Kilos. Half Year	12.25				12.75			
Pub. Stage	1	2	3¹	3x	1	2	3¹	3x
15–19					5			
20–24	5				20	5		
25–29	4	1	1		13	4	1	1
30–34	2		1		4	4	1	0
35–39					3	0		0
40–44					1	1		1
45–49								
50–54								
55–59								
60–64								
65–69								
70–74								
75–79								
80–84								
85–89								
Number	11	1	2		46	14	2	2
Average	(26.14)	(27.5)	(30.)		25.65	28.21	(30.)	(32.5)
Sigma	(3.75)				5.96	(5.71)		(5.00)

Year 13

Kilos. Half Year	13.25				13.75			
Pub. Stage	1	2	3¹	3x	1	2	3¹	3x
15–19	8				6			
20–24	50	18	2	5	49	21	12	5
25–29	40	28	5	9	78	46	8	17
30–34	26	12	4	1	46	47	14	28
35–39	5	5	2	11	7	13	8	31
40–44		0	3	3	2	9	3	23
45–49		1		2				9
50–54				2				5
55–59								2
60–64								
65–69								
70–74								
75–79								
80–84								
85–89								
Number	129	64	16	33	188	136	45	120
Average	26.84	28.18	32.19	33.09	27.09	30.41	30.5	35.20
Sigma	4.84	5.01	6.48	8.03	4.68	5.84	6.19	7.79

Year 14

Kilos. Half Year	14.25				14.75			
Pub. Stage	1	2	3¹	3x	1	2	3¹	3x
15–19	5	2	1		3	2	1	1
20–24	40	28	3	6	17	22	5	11
25–29	61	71	21	18	34	52	7	34
30–34	33	54	25	40	26	49	28	51
35–39	6	20	18	70	15	22	28	85
40–44		13	6	43	1	7	7	71
45–49			1	20		1	4	39
50–54				11				21
55–59				6				12
60–64				3				2
65–69								2
70–74								0
75–79								1
80–84								1
85–89								
Number	145	188	74	216	96	155	80	331
Average	27.83	30.18	33.59	37.77	29.97	30.79	34.62	38.60
Sigma	4.49	5.56	5.49	7.61	4.90	5.68	5.00	6.48

Year 15

Kilos. Half Year	15.25				15.75			
Pub. Stage	1	2	3¹	3x	1	2	3¹	3x
15–19	1	1	1					
20–24	10	12	6	5	1	6	4	1
25–29	14	31	8	22	6	19	7	17
30–34	18	46	19	58	8	7	17	42
35–39	7	16	19	85	5	7	11	76
40–44	1	3	11	80	0	2	6	83
45–49		2	1	64	1	1	2	69
50–54			1	20				38
55–59				15				28
60–64				6				12
65–69				3				5
70–74								0
75–79								0
80–84								2
85–89								
Number	51	111	66	356	21	42	47	373
Average	29.55	31.15	34.89	40.07	32.60	30.49	33.98	42.60
Sigma	5.44	5.81	6.72	8.42	5.34	6.04	6.18	9.50

Year 16

Kilos. Half Year	16.25				16.75			
Pub. Stage	1	2	3¹	3x	1	2	3¹	3x
15–19	1							
20–24	0	3	1	2		1		1
25–29	2	4	5	6	1	1	2	1
30–34	0	5	10	27		1	1	7
35–39	2	2	5	62		4	1	23
40–44	1		2	54			1	29
45–49				47				35
50–54				41				17
55–59				25				25
60–64				6				11
65–69				2				7
70–74				4				2
75–79								2
80–84								
85–89								
Number	6	14	23	276	1	7	5	160
Average	(31.07)	29.65	32.98	43.77	(27.5)	(33.21)	(33.5)	48.48
Sigma	(6.37)	4.90	4.83	9.45		(5.93)	(0.68)	9.90

Years 17 and 18

Kilos. Half Year	17.25				17.75			18.25	18.75
Pub. Stage	1	2	3¹	3x	2	3¹	3x	3x	3x
15–19									
20–24									
25–29									
30–34				1				2	1
35–39			3	11			4	2	
40–44				29			10	1	
45–49				17			8	1	1
50–54				13			4	6	
55–59				10			10	4	1
60–64				8			4	4	
65–69				6			3	0	
70–74				3			2	2	1
75–79				1				0	1
80–84				0				1	
85–89				1					
Number			3	100			45	23	5
Average			(37.5)	49.49			51.94	55.	
Sigma				10.80			9.69	13.42	

weaker than the pre-pubescents. This is unprecedented and points to the conclusion that if pubescence takes place at so late a date as this, it causes a temporary diminution in motor force. (This coincides with the unscientific belief that periods of rapid physiological change are periods of vulnerability.) This is by no means the case for others than this restricted group. It is necessary to follow the individuals themselves through these stages to arrive at positive results.

Herein have been presented three features, two of structure and one of function. We will now turn to the discussion of the complex result of function, success in scholarship.

Scholarship and Pubescence

"Scholarship" is a measure of complex function. It is unlike weight and height, which are purely physical, and is more allied to strength. Success in school life means the ability to get "marks," and satisfy the teacher in daily recitation and upon examinations that the subjects studied are relatively mastered. This scholarship mark is not an evidence of such mental ability as will be surely correlated with after success in life though it may be so correlated. It does, however, stand for the individual's ability to adapt himself to his immediate environment and to win success in his immediate sphere. It is a measure of application, ability and cleverness.

There are two methods that may be used. We may take similar age groups in different grades of the school and demonstrate the average pubescence of these groups which are the same in age while they differ in term. For example, let us take the age group of the half year 14 to 14.50 and estimate the pubescence percentage of each term for this age and state the result below:

TABLE XV.

PUBESCENCE PERCENTAGE AND SCHOLARSHIP.

14.25

1st Term.....	57.1
2d "	62.7
3d "	60.6
*4th and 5th Terms..	83.9

It is evident that the further advanced the group is in term† (hence in scholarship) the more advanced they are in

*NOTE. *See Table XIV for relative size of fourth and fifth term groups.*

†NOTE. *There are eight terms of one half year each in the high school course.*

physiological age. This fact is strikingly shown by Table XV. The difference between the first term group and the fourth and fifth terms group is 26 per cent units. The group in the highest terms is more than 50 per cent more advanced than the first term group. At 13.25 the group in the third term is 70 per cent, while the group in the first term is only 31.8 per cent, i.e., less than half as much. These percentages have been worked out for the whole series and are given below:

TABLE XVI.

PUBESCENCE PERCENTAGE AND SCHOLARSHIP.

Age.....	12.25	12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75
1st Term.....	(10.4)	18.8	31.8	42.8	57.1	68.6	76.7	87.3	93.2	97.5	98.0	100.0
2d "		(19.0)	30.9	51.5	62.7	72.6	81.4	88.6	95.4	97.2	100.0	100.0
3d "			(70.0)	51.2	69.6	78.4	85.9	94.6	96.2	94.0	100.0	100.0
4th-5th Terms				(75.0)	83.3	93.2	89.8	94.1	99.6	100.0	98.0	100.0
All.....	(10.0)	(18.5)	31.9	44.9	59.8	71.6	80.4	89.6	95.3	97.0	99.1	100.

The average movement per term interval in per cent units for each year has been calculated from the above and is given below.

13 Years	+	2.43
14 "	+	8.46
15 "	+	3.32
16 "	+	1.48

If we interpolate in this table the age value for the pubescence percentage as calculated from the average pubescence value of all given on the lowest line, we have the following table of age:

TABLE XVII.

Age.....	13.25	13.75	14.25	14.75	15.25	15.75	16.25
1st Term.....	13.2	13.7	14.2	14.6	15.1	15.6	16.1
2d "	13.2	14.0	14.4	14.9	15.3	15.7	16.3
3d "	(14.7)	14.0	14.6	15.1	15.5	16.2	16.5
4th-5th Terms		(14.9)	15.4	15.1	15.8	16.2	17.5

It has been calculated from Table XVII that the average movement is plus .4 years.

This is a clear demonstration of the pubescence constituency value in terms of age in years and calculated on the basis of success in scholarship. The higher grade scholars of equal ages are demonstrably older in pubescence to the values given in years.

A second method, and one that is, if possible, somewhat more definite and conclusive than the one just used, is given below. The age groups are divided into pubescence classes and the actual performance in scholarship of each group is recorded. (See next page.)

TABLE XVIII.*

SCHOLARSHIP—PUBESCENCE—AGE
1ST YEAR HIGH SCHOOL BOYS.

Hours of Failure.	Age and Pubescence Stage.																			
	13				14				15				16				17			
	1	2	3'	3x	1	2	3'	3x	1	2	3'	3x	1	2	3'	3x	1	2	3'	3x
0-5	109	63	14	01	63	80	33	150	17	28	24	120	2	2	0	56				15
5-10	40	19	6	19	31	34	11	56	8	18	6	54	1	2	0	37				5
10-15	18	10	3	12	18	20	9	32	10	19	12	40	0	0	0	16				7
15-20	23	13	2	4	22	19	9	21	3	4	8	21	1	1	0	15				4
20-25	13	3	0	2	7	13	1	11	1	3	1	13	0	3	0	6				1
Total No.	203	118	25	98	141	164	63	270	39	66	46	257	4	8	0	130				32
Percent Passing	73	72	75	82	66	67	70	76	64	69	65	71	(75)	(50)		72				82
Percent Failing.	27	28	25	18	34	33	30	24	36	31	35	29	(25)	(50)		28				28

Explanation. Each student has 24 hours of prepared work on which he is marked. He may fail in any number from zero to twenty-four. All who fail in more than 9 hours are not permitted to advance to the next grade, and are hence "failures"; all having nine or less "pass."

It will be observed that 9 per cent, 10 per cent, and 7 per cent more post-pubescents "pass" at the respective ages of 13, 14, and 15 than do the pre-pubescents. Hence, we have corroborated the findings of the previous method.

Summary

Post-pubescents are different from pre-pubescents mentally as well as physically, and the difference is enough to cause us to take it into account whenever we make any observations whatsoever upon mental characteristics of the ages about puberty.

This has never been taken into account when considering boys. Marro has noted the difference in conduct between girls who have menstruated and those who have not. It is fair to state that any investigator disregarding this classification as a fundamental means of grouping the population he studies will find his results subject to a correction of 9 or 10 per cent. This error is enough to vitiate any results whatsoever.

*NOTE. *This table will bear extended analysis though only one feature is discussed here. The average failure, sigma, etc., may be calculated and information gained thereby. The distribution of individuals within the passing and failing groups is of great moment, but does not bear upon the central thesis of this paper so much as it does upon constructive pedagogy. Its full discussion may well be reserved.*

While it is not the province of this part of the paper to make application of its results, one definite point bearing upon school work may be mentioned. We must not expect so much in school work from the pre-pubescent or the pubescent as we do from the post-pubescent. The immature groups are obviously less fitted for the strain of high school work. Fifty per cent more of them fail at 13 years than do the mature group. They are held equally blameworthy and without reason. Some adjustment of pedagogical treatment must be made to meet these conditions. for there is a great waste of effort when we try to treat dissimilar students with the same means and expect to get similar results. The immature should be kept in the paternal atmosphere of a special school intermediate between the elementary and high school, and allowed to go to the high school only when he becomes mature enough to meet with relative success under less restricted environment. This would give the immature appropriate educational opportunities, and rid the high school of a great deal of dead timber.

Since there has been a great hue and cry raised about the lack of success of high school students in their studies, and the parallel fact that they leave the high school after a few months or a year, it is apparent that any real fact that explains this failure should meet with earnest consideration.

SECTION III

1. CORRELATION OF PHYSICAL MEASUREMENTS AND SCHOLARSHIP

Scholarship and Weight

We are familiar with the investigations of Porter (Physical Basis of Precocity and Dullness, St. Louis Academy of Sciences, 1893) and of Smedley (46th Annual Report, Board of Education, Chicago, 1899-1900) which showed in children of the same age that weight and school grade were correlated. That is to say, the higher the grade, the greater was the weight. This is undoubtedly true. Smedley selects the most striking case, that of the twelve year group, for detailed presentation. This is given in Table XIX.

This table demonstrates a difference of 8.94 kilos in weight between those of the same age six years apart in scholarship.

Similar results were gained through the whole of the present investigation, but for reasons given below the whole series has not been worked out. For the sake of comparison the re-

TABLE XIX.

CORRELATION OF WEIGHT, ETC., AND SCHOLARSHIP (SMEDLEY).

Grade	Number	M.M. Average Height	KILOS. Average Weight	KILOS. Average Right Hand Grip
2	4	1333	29.51	16.75
3	19	1377	33.59	20.03
4	84	1409	34.97	20.22
5	134	1422	35.59	21.06
6	143	1449	36.13	21.40
7	95	1451	37.15	22.31
8	18	1448	38.45	23.31

sults for the half year group 14.75 are given.

TABLE XX.

WEIGHT AND TERM. 14.75 YEARS.

Term	Kilos. Weight
1	42.2
2	44.6
3	44.7
4	46.0

This table shows a difference of 3.8 kilos in weight between those of the same age 1 1/2 years apart in scholarship. Theoretically for six years' difference in scholarship, the weight difference would be 15.4 kilos, considerably greater than the difference given by Smedley for six scholarship years' difference at 12 years of age.

These investigations present a fact which is misleading; for it is easy to assume that scholarship and weight are in casual relation to each other. This is not necessarily true, for it will be shown that there is little or no relation whatever between scholarship and weight except in so far as their relation to pubescence relates them to each other. Weight, height, strength, scholarship and all features both physical and mental of the ages about puberty, are effects of many causes. Weight and scholarship are both affected strongly in the same direction by pubescence. Hence they show a positive correlation, but this correlation is in its greatest part only secondary to their primary correlation with pubescence.

There are two ways we can prove this thesis: First, indirectly, we can mathematically determine the influence of pubescence on weight, and observe by trial its coincidence with the similarly determined influence upon scholarship. If these are found equal or their variation determined, the other factors of weight and scholarship respectively become so much the more isolated and subject to analysis. This opens the door to a wide field of investigation. This method is also subject to

misinterpretation for, even if the calculated movements should coincide, we would not be able to state positively that the coincidence was not accidental and that factors have neutralized each other.

The second method which is emphatically direct is one that will be followed here. We will eliminate pubescence as a factor, and observe directly whether or no there is any correlation other than this.

It will be observed that Porter and Smedley both compared groups of the same age in different terms without regard to the fact that these groups differed widely in their pubescence characteristics. These characteristics have been discovered and shown above. It is well to repeat a portion of the data for the sake of having a concrete example:

TABLE XXI.

WEIGHT—PUBESCENCE—SCHOLARSHIP.
AGE 14.75.

Term	Weight Kilos.	Pubescence Stages 1	2	3	Percentage All
1st	42.2	18%	27%	55%	68.6
2d	44.6	15	25	60	72.6
3d	44.7	14	16	70	78.4
4th and 5th	46.0	3	7	89	93.2

This table gives the weight increase with term and the pubescence increase with term together so that they can be readily compared.

We have seen that the post-pubescents weigh more than any other group. Hence, the greater the number of post-pubescents in any group the greater will be the weight of the group. This fact accounts for the results gained by Porter and Smedley.

If the similar pubescence groups of different terms differ from each other in weight, then there is a primary correlation of term and weight. If they do not differ in weight, then there is no primary correlation but a secondary correlation through pubescence. Table XXII enables us to make a comparison and decide this point.

From mere observation of this table it will be seen that there is but little difference between similar pubescence groups of different terms, and that these small differences vary as to direction; some being plus and some minus. In order to ascertain if there is any consistent difference for minus or plus, the differences have been tabulated (regarding only those where there are sufficient data). Thus in 32 cases there is a plus average movement of .08 kilos.

This +.08 kilos average difference between similar age and

TABLE XXII.

PUBESCENCE—WEIGHT—SCHOLARSHIP.

Age	Pubescence	1st Term	2d Term	3d Term	4th Term
13.25	1	34.02	°35.5		
	2	36.46	°37.5		
	3	48.39	°57.5		
13.75	1	35.09	36.89		
	2	37.02	38.41		
	3	43.14	45.88		
14.25	1	35.38	35.94	36.25	
	2	38.36	39.46	39.50	
	3	45.93	44.51	45.50	
14.75	1	38.46	38.18	35.84	
	2	39.11	38.28	39.72	°37.5
	3	45.83	49.54	47.82	46.67
15.25	1	38.15	37.5	°39.5	°35.
	2	38.5	39.16	°40.	°37.5
	3	48.14	46.9	49.44	48.50
15.75	1	38.82	37.5	°47.5	°32.5
	2	40.45	40.31	°44.16	°62.5
	3	49.12	48.31	50.46	52.83
16.25	1		°32.5	°37.5	
	2		°37.5	°37.5	
	3	52.70	50.45	50.14	50.23
16.75	1				
	2			°35.	
	3	53.72	53.42	54.17	52.15

physiological age groups which differ only in one term's scholarship is only a small part of the difference between similar age groups which differ in physiological age as well as term. The rest of this difference we can fairly state is due to the hitherto neglected factor, physiological age. The difference between weight averages of similar groups in contiguous terms varies. At 14.75 it is -.17 while the whole difference is 1.26 kilos, which would indicate that the 1.43 kilos difference is due to difference in physiological age. We are warranted in the conclusion that the major part of the apparent correlation of weight and scholarship is due to their respective relations to physiological age. This is obviously only a preliminary step in the analysis of the factors producing the completed result - scholarship.

Scholarship and Height

Similar analysis of height, scholarship, and pubescence stage give similar results as indicated by Table XXIV.*

*NOTE. *See original work for author's analysis.*

TABLE XXIV.

PUBESCENCE—HEIGHT—SCHOLARSHIP.

Age	Stage	1st Term	2d Term	3d Term	4th Term
13.75	1	145.8	146.5		
	2	149.9	151.2		
	3	155.4	156.8		
14.25	1	146.0	147.3	149.4	
	2	149.6	149.5	151.8	
	3	156.8	158.1	156.4	
14.75	1	147.3	147.3	147.6	°145.
	2	149.9	150.7	151.5	°147.
	3	158.0	159.8	159.3	159.9
15.25	1	149.4	148.8	°153.	°145.
	2	150.7	154.2	151.6	°143.
	3	160.3	159.7	162.5	162.2
15.75	1	151.4	°145.5	°149.	°141.
	2	153.2	151.2	°157.5	°159.
	3	163.4	162.5	162.9	164.3
16.25	3	164.1	165.5	164.9	167.

Scholarship and Strength

A similar analysis has been made of the records of strength of grip (right hand) and term.

TABLE XXVI.

PUBESCENCE—STRENGTH—SCHOLARSHIP.

Age	Pubescence	1st Term	2d Term	3d Term	4th Term
14.25	1	26.72	28.96	26.50	
	2	30.32	30.01	29.38	
	3	36.55	38.02	37.40	
14.75	1	29.16	30.70	28.84	°22.5
	2	30.24	30.74	30.00	°34.16
	3	38.03	39.40	39.01	39.66
15.25	1	28.89	29.65	°35.5	°29.16
	2	30.48	33.39	30.56	°20.37
	3	38.91	40.04	41.23	41.47
15.75	1	33.39	°33.33	°27.5	°37.5
	2	28.37	30.18	°32.5	°45.00
	3	41.31	41.65	43.87	45.36

Results

We have seen that scholarship does not bear any marked primary relation to weight, height, strength, etc., though they are all affected in the same direction of pubescence. The only real relations of scholarship are: a probably negative relation

to weight, a probably positive relation with height, and a possibly positive relation to strength. Their mutual relation with pubescence is the most important feature.*

2. GROWTH RATES

It is customary to state that the period of pubertal growth acceleration in boys extends from 13 to 16 years, in girls from 12 to 14 years. These facts have been gained as a rule from comparison of average measurements of the different years, and are hence subject to many errors. This has been clearly shown by some investigators, and in many cases the actual growth changes in the individuals themselves have been recorded and averaged. These latter results are trustworthy in so far as their information may go.

At the period under consideration, however, it is obviously absurd to assemble growth increments into age groups alone. The boys in any one of our age groups will be passing through different stages of their development. Some will be years past their pubescence, others will live years before beginning their pubescence, others, again, are actually in the period of pubescence. As yet we have not seen any data on growth rates which take this factor into consideration. Wissler (Growth of Boys, Am. Anthropologist, January, 1903) has demonstrated that the growth rates bear plus correlations to the growth rates of the nearest years, and minus correlations to those more remote.

Our classification must, however, regard the factors of physiological age.

Classification of Growth Periods

For the purpose of this study there are at least seven classes for each year. Those who are in stage one (pre-pubescence) at their first measurement, may remain in stage one, pass to two (pubescence), or all the way to three (post-pubescence), before the second measurement. Those in two may remain there or pass to three. Those in three will forever remain there. Those who were recorded as being for the first time in stage three are separated from those who are unknown as to their past pubescence (owing to the fact that they were in three at the first examination), and those who are known to be more

*AUTHOR'S NOTE. *In elementary schools the author found the contrary correlation, i.e., poor scholarship related to advanced "maturity." Ped. Sem., June, 1908.*

than one-half year past pubescence. We have, therefore, the following classes:

1 to 1
1 to 2
1 to 3¹
2 to 2
2 to 3¹
3¹ to 3²
3ˣ to 3ˣ

Examinations were made in May and October, making a five-month interval including the summer vacation, and a seven-month interval including the bulk of the school year.

The average increases in weight, height, and strength for winter periods are given in Tables XXVIII, XXX, and XXXII.* The date of the second examination determines the age class.

TABLE XXVIII.

SEVEN MONTHS' WEIGHT INCREASE—PUBESCENCE CLASSES.
1201 RECORDS.

AVERAGES (KILOS.)

Pubescence Classes, 1st Meas. / Pubescence Classes, 2d Meas.	1 / 1	1 / 2	1 / 3	2 / 2	2 / 3	3¹ / 3²	3ˣ / 3ˣ
Ages 12	0.0	°1.5					
Ages 13	1.59	2.23	°3.5	2.25	2.76	°3.5	4.25
Ages 14	1.06	2.43	4.39	1.91	3.59	3.53	3.70
Ages 15	1.58	2.90	4.5	1.78	3.49	3.94	3.10
Ages 16	1.5°		°3.5	°2.	4.04	4.03	2.89
Ages 17				°2.5	°4.	4.25	1.84
Ages 18							.81
Averages,	1.21	2.55	4.44	2.87	3.47	3.94	3.15

VARIABILITIES.

Pubescence Classes, 1st Meas. / Pubescence Classes, 2d Meas.	1 / 1	1 / 2	1 / 3	2 / 2	2 / 3	3¹ / 3²	3ˣ / 3ˣ
Ages 13	1.23	1.94		.82	1.80		2.38
Ages 14	1.87	1.87	.99	1.54	2.06	2.44	1.95
Ages 15	2.07	2.20	.00	1.48	2.20	1.89	1.95
Ages 16			.00		1.27	1.46	2.36
Ages 17							1.63

Weight Increase

It will be observed immediately that each pubescence interval class has its characteristic growth rate. These rates vary from each other in some cases 200 per cent.

The growth rate of the pre-pubescents who remain pre-

*NOTE. For similar data on summer, five months' period, see original work of author.

TABLE XXX.

SEVEN MONTHS' HEIGHT INCREASE—PUBESCENCE CLASSES.
1197 RECORDS.

AVERAGES (Cm.)

Pubescence Classes, 1st Meas. / Pubescence Classes, 2d Meas.	1 / 1	1 / 2	1 / 3	2 / 2	2 / 3	3¹ / 3²	3ˣ / 3ˣ
Ages 12	°2.5	°3.5					
13	2.68	3.54	°4.5	2.04	4.23	°7.	5.29
14	2.56	3.56	5.5	3.24	5.35	5.24	4.31
15	2.11	3.21	°6.5	3.27	4.58	4.70	3.49
16	°1.5		5.1	2.5	4.78	4.68	2.85
17				°1.5	°8.5	°5.	1.05
18							.87
Averages,	2.45	3.44	°5.2	2.99	4.78	4.65	3.07

VARIABILITIES.

Pubescence Classes, 1st Meas. / Pubescence Classes, 2d Meas.	1 / 1	1 / 2	1 / 3	2 / 2	2 / 3	3¹ / 3²	3ˣ / 3ˣ
Ages 13	.93	1.44		.83	1.40		1.08
14	.80	1.30	.53	1.39	1.30	1.42	1.44
15	.49	1.29	°1.00	.94	1.56	1.57	1.09
16	°.00		.91	.00	1.09	1.23	1.60
17							1.44
18							.09

TABLE XXXII.

SEVEN MONTHS' STRENGTH INCREASE—PUBESCENCE CLASSES.
1134 RECORDS.

AVERAGES (KILOS. GRIP RIGHT HAND).

Pubescence Classes, 1st Meas. / Pubescence Classes, 2d Meas.	1 / 1	1 / 2	1 / 3	2 / 2	2 / 3	3¹ / 3²	3ˣ / 3ˣ
Ages 13	2.65	3.38		1.14	4.06		6.48
14	2.13	3.08	0.95	2.63	6.65	5.50	6.85
15	1.59	4.69	°8.10	2.50	5.24	6.70	6.30
16			°2.50	3.75	6.55	5.82	6.29
17							5.61
18							5.12
Averages,	2.12	3.72	°5.00	2.50	5.12	5.84	6.02

VARIABILITIES.

Pubescence Classes, 1st Meas. / Pubescence Classes, 2d Meas.	1 / 1	1 / 2	1 / 3	2 / 2	2 / 3	3¹ / 3²	3ˣ / 3ˣ
Ages 13	4.55	4.72		5.14	4.45		8.27
14	4.25	4.46	3.60	4.83	4.98	4.08	6.73
15	5.57	4.66	°2.26	5.00	4.99	5.69	5.81
16			° .00	4.02	3.31	5.22	6.46
17							6.76
18							6.09

pubescents (1 - 1) is the lowest of all; those who are post-pubescents for the first time (3^1 - 3^2) have the highest growth rate. The 1 - 2 class grows faster at each age than the 1 - 1. The 1 - 3 class, cases where the whole stage of pubescence is passed through within the interval of measurement, shows a very high rate (4.44 in seven months). There are very few who develop so rapidly as this, and the data are meagre.

The 2 - 2 class contains those who are the slowest in developing after beginning their pubescence. They show a fair increase in weight, though not so much as those (2 - 3) who finish their pubescence.

Those who are in their first year of post-pubescence, the 3^1 - 3^2 class, show the highest growth rates with practical uniformity throughout the years. The 3x - 3x class (composed of those of whom we do not know the time elapsed since puberty) shows a striking and consistent feature. The rate at 13 years is the highest recorded in summer or winter series, each successive year shows a diminution, until at eighteen it is the least of all. The thirteenth year 3x - 3x class must of necessity be mainly 3^1 - 3^2, for there are very few (sixteen per cent) post-pubescents at twelve years, as we have noted in our previous records. The same thing is true of fourteen years to a less degree.

If we refer to our previous discussion of the constitution of this 3x group as to their number of years post-pubescence, we will see that the greater the average number of years post-pubescence the less the growth rate will be on the tables just given. For instance, the group 13.75 has a value of only .70 years post-pubescence while the winter growth rate of the thirteenth year group is 4.25 kilos. The group 17.75 on the other hand has an average of 3.28 years post-pubescence, and a winter growth rate of 1.84 kilos for seventeen years (.81 kilos for eighteen years). The difference between the 3^1 - 3^2 group and the 3x - 3x group at seventeen years is most striking. On these facts we are able to determine a rational growth curve, and understand what we may expect in the way of growth acceleration.

Boys (above 12 years) do not grow, on the average, more than three kilos a year until they begin their pubescence, no matter how late that may be. On beginning pubescence their acceleration commences. It is slow at first; if pubescence is short their rate is very high, if slow the rate is lower. The most rapid rate is attained at and immediately after their transition to the mature stage. The rate gradually declines, reaching a lower point three or four years after pubescence than it had in pre-pubescence.

There are two results of this portion of the work that must work a radical change in our ideas of growth.

(1) There is no "pre-pubescent acceleration," though the "pre-pubescent acceleration" has been referred to ever and anon. There is perhaps a slight pre-pubertal (1 - 2) acceleration, but it is insignificant in comparison to the pubertal (2 - 3 and 3^1 - 3^2) acceleration which continues well into post-pubescence.

(2) Acceleration bears but a slight relation to age. The prime index of acceleration is the physiological period. This is additional proof of our main thesis.

Height

What has been said upon weight may be repeated almost word for word about height. There is the same clean-cut definition of results, with the same dependence upon pubescence. There is evidence, however, that the 1 - 1 and the 1 - 2 groups increase more rapidly in height than they do in weight. Using the most rapidly growing class as a basis for comparison, the 1 - 1 groups grow 22 per cent and the 1 - 2 classes 17 per cent faster in height than weight.

Strength

Our strength increments show some instructive variations from the purely structural measurements.

The main features are the same: acceleration beginning with pubescence, reaching a rapid rate during late pubescence and continuing into post-pubescence. Here we notice a decided difference between summer and winter records. The summer records for group $3\underline{x}$ - $3\underline{x}$ show a decrease from 6.88 kilos at 13 years to .89 kilos at 17 years, and this is in accordance with weight and height records. The winter records, however, show a high rate of increase continued through to the eighteenth year, which is 5.12 kilos, while the summer record for the seventeenth year is .89 kilos. This may possibly be a seasonal variation, and if it is so it is at variance with all our preconceived ideas on the subject. It is probable that this steady winter increase is due to the physical training received in the winter and not continued into the summer.

Again, the slow developing group 2 - 2 shows a very slight summer gain, averaging less than a kilo for five months, while the winter averages are over six times as great. The fast-developing group 1 - 3 shows a similar difference. Here is perhaps an item for a brief for physical training.

Perhaps it is an evidence of the relaxing nature of heat, perhaps an evidence of seasonal variation of alternate appendicular and somatic function. At any rate, we have a new fact to use as a basis for further exploration.

Rapidity of Development

The rapidity of development, the rate of passage between the several stages and the probability of beginning or ending of pubescence are all features of great importance that have been only indirectly presented in the foregoing discussion.

Table XXXIII gives the comparative rate of change for each age group during a seven-month winter interval.

TABLE XXXIII.

RAPIDITY OF DEVELOPMENT. 7 MONTHS WINTER INTERVAL. 1471 CASES.

	Age	12	13	14	15	16	17	18
Pubescence Stage Movement	1-1	2	47	119	33	4		
	1-2		27	60	50	0		
	1-3¹		2	11	0	4		
			76	190	83	8		
	2-2		14	47	26	4	2	
	2-3¹		18	61	88	26	4	
			32	108	114	30	6	
	3¹-3²			43	68	17	4	
	3ˣ-3ˣ		23	175	248	181	57	4
NUMBER OF CASES		2	132	516	514	236	67	4

This table gives us the rate of flow of pubescence, and from it we can calculate the probability of length of pubescence, etc. The data are not sufficient to show a smoothness of result throughout, and but a few points are emphasized.

Of those who are in pubescence, at the age of fourteen, 43 per cent remain there during this seven-month interval as against 22 per cent at fifteen and 13 per cent at sixteen years. This is positive evidence in support of the thesis that the later the change the more rapid it is.

A comparison of this table with data from the summer flow (1635 cases) shows that the pubescence change is far more rapid in the summer.

Despite the fact that the winter period is two months longer than the summer, the summer is obviously and markedly the season for rapid development. The whole range of results as to seasonal growth given by Malling-Hansen must be reviewed in the light of these and other foregoing facts.

TABLE XXXIV.

SUMMER (5 MONTHS) AND WINTER (7 MONTHS).

RAPIDITY OF REMOVAL FROM PUBESCENCE TO POST-PUBESCENCE. PERCENTAGE OF THOSE PROGRESSING DURING THIS INTERVAL.

Ages.	13	14	15	16	17
Summer—5 Months	75	90	91	87	100
Winter — 7 Months	56	50	77	80	86

Conclusions

(1) Growth rates are dependent upon pubescence periods and not upon age.

(2) Accelerations in weight, height, and strength occur at the same time.

(3) The growth impulse makes itself felt strongly in the early part of pubescence, reaches its climax at or immediately after the change to post-pubescence. It may continue for some short time after the change. This conclusion controverts the usual belief held first by St. Hilliare that growth in weight and growth in height were mutually imcompatible. It also refutes the accepted theory that gain in strength does not occur during rapid growth.

(4) The more rapid the development, the more rapid is the gain in weight, height, and strength.

For the purpose of exhibiting the coincidence (or lack of it) between the results of the study of averages and individual cases, the following data of successive examinations of individuals are given.*

TABLE XXXV.

CASE I. H. D. G. Ht. 147.6 Wt. 34.40 (At first examination).

Age	13.7	14.2	14.7	15.2	15.7
Pub. Stage	1	1	1	2	3
Inc. in Ht. Cm.		2.0	2.	3.	4.5
Wt. K.		1.35	0.	3.75	3.75
Str. K.		1.	1.	4.	4.

CASE II. H. D. Ht. 137.2 Wt. 33.55

Age	12.11	13.4	13.11	14.4	14.11	15.4
Pub. Stage	1	1	½	2	3	3
Inc. Ht.		2.	2.6	2.9	4.6	3.4
Wt.		1.7	1.65	3.1	3.5	4.2
Str.		+3.	—1.	4.	3.	3.

*NOTE. *This was perhaps the first appearance in literature of records of successive growth and development measurements of individuals (vs. group-records) from year to year - so well carried out later by Terman, Scholz, et al.*

CASE III. A. J. F. Ht. 148.0 Wt. 41.7 Str. 32

Age	13.8	14.3	14.8	15.3	15.8
Pub. Stage	1	1	1	3	3
Inc. Ht.		2.	1.7	5.4	4.5
Wt.		.0	.9	4.5	5.3
Str.		—2.	—1.	9.	4.

The above cases follow the average results and are somewhat typical.

The following cases show a somewhat continued acceleration which lasts through a year and a half or two years after pubescence.

CASE IV. E. W. Ht. 151.4 Wt. 31.5 Str. 30

Age	13.10	14.5	15.10	15.5	16.10	16.5	17.1
Pub. Stage	2	2	3^1	3^2	3^3	3^4	3^5
Inc. Ht.		1.8	4.3	4.6	3.2	4.4	1.2
Wt.		4.35	1.9	4.25	2.75	4.55	.7
Str.		4.	4.	5.	2.	10.	0.

This case shows four half years of rapid growth terminated suddenly at 16.10 years.

The following case shows a gradually diminishing acceleration.

CASE V. A. B. Ht. 141.8 Wt. 31.8 Str. 26

Age	14.8	15.1	15.8	16.1	16.8	17.1
Pub. Stage	2	3^1	3^2	3^3	3^4	3^5
Inc. Ht.		7.4	4.2	3.5	3.1	.8
Wt.		5 3	3.4	2 25	3.	1.25
Str.		2.	7.	3.	2.	2.

The weight acceleration often continous longer than the height acceleration.

TABLE XXXVI.

CASE VI. R. N. T. Ht. 161.3 Wt. 44.8 Str. 30

Age	14.2	14.9	15.2	15.9	16.2	16.9	17.2
Pub Stage		2	3	3	3	3	3
Inc. Ht.		3.7	3.2	2.2	.3	.8	.4
Wt.		3.6	3.3	1.3	1.75	1.75	2.5
Str.		6.	2.	6.	—1.	4.	1.

In this case the boy was unusually tall at the beginning of the series.

Sometimes there occurs a second acceleration. This seems

to be oftenest the case when the acceleration occurring at the typical time is weak and abortive. This is shown by Case VII.

TABLE XXXVII.

CASE VII. W. G. Ht. 142. Wt. 29.4 Str. 24

Age	13.0	13.7	14.0	14.7	15.0	15.7	16.0
Pub. Stage	2	2	3	3	3	3	3
Inc. Ht.		2.	3.	3.7	2.3	4.5	3.
Wt.		3.1	1 25	2.3	—.3	5.85	3.
Str.		1.	3.	7.	7.	4.	4.

NOTE. The author is fully aware that errors of observation will account for some of the irregularities shown above. These errors will correct themselves, however, where the measurements are repeated as shown. There is little probability of the height error exceeding .5 cm., the weight 1 k. or the strength 3 kilos.

These cases express in a different way the fact of the dependence of growth accelerations upon pubescence stages.

The character of the acceleration depends somewhat upon many factors other than age and pubescence, for there must be reasons for the irregularities shown in these individual cases and some reasons for the variabilities tabulated. Race, heredity, social, and hygienic condition have to be recorded as influencing growth and the growth acceleration; all those continue to show their influence when pubescence is determined as a factor and eliminated. Scandinavian, Scotch, light-haired Germans are tall races; Italians and French are among the shortest of our group. Children born here of Jewish parentage outstrip their parents, and furthermore it is a general rule that all children of mixed parentage are more like the larger parent in growth.* Younger sons often outstrip older brothers at pubescence, and pass them in actual weight and height, if the difference is less than two years in age. Several instances of this have occurred in this series of cases and are worthy of special report. The upper middle social stratum is most favorable for large growth. The upper middle hygienic stratum appears also to be the most favorable. The very poor and vicious often accelerate early and incompletely, passing for the nonce those in more favorable circumstances; this is probably due to early exposure and sex influences.

(The author continues with an analysis of correlation of tooth eruption with physical measurements, a table on correlation on weight, height, and menstruation, an assembly of physiological age signs throughout life and the following statement.)

**NOTE.* *See Boas and Crampton, Report of Federal Immigration Commission.*

CONCLUSION

The writer has attacked the general problem of the significance of physiological age in three studies. One, the first, is finished as regards the central thesis; the other two are but sketched. By-products of these theses are too numerous ever to reach a stage of completion. In fact, the importance attached to this work rests upon the far-reaching - nay, universal application of this theme. There is no biological or humanistic endeavor which will not be affected by this change of base.

In closing, the writer may well repeat the words of his previous remarks: "It is my firm conviction, founded upon the evidence herein presented, that all of our observations of the young adolescent, whether they be anthropological, medical, educational, or social, must rest upon this definite classification."

THE WORK OF C. WARD CRAMPTON, M.D.
PHYSIOLOGICAL AGE
(to February, 1944)

Pubescence. Am. Anthrop., Oct. - Dec., 1904.

The influence of physiological age upon scholarship. Physiol. Clin., June, 1907.

Statistical methods (used in the Physiological Age Study). Am. Phys. Educ. Rev., Jan., 1908.

Physiological age - A fundamental principle. Am. Phys. Educ. Rev., March, April, May, June, 1908.

Anatomical or physiological age versus chronological age. Pediatrics, June, 1908.

Anatomical or physiological age versus chronological age. Pedagog. Sem., June, 1908. (Reprinted from Pedagog. Sem. as Bull. 1 on Physiological age, etc., by the Committee on Physical Welfare of School Children, New York City.)

The differences between anatomic, physiological, phychological, and chronological age as causes of derailment. Am. J. Obstet. and Dis. Women and Children, 1910; Proc. Nat. Assn. for the Study and Educ. of Except. Children.

The significance to the physician of physiological age. Am. J. Obstet. and Dis. Women and Children, 1912.

The significance of physiological age in education. Reprinted from Trans. 15th Internat. Cong. on Hyg. and Demography, 1913.

Physiological age and the school. J. Genet. Psychol., June, 1930.

Why don't I grow? Parents' Mag., Aug., 1938.

(With E. De Alton Partridge, Ph. D., joint author): Social adjustments associated with individual differences among adolescent boys. J. Educ. Sociol., October, 1938.

Quotation from "Significance of Physiological Age in Education" (Crampton), Transactions of the Fifteenth International Congress on Hygiene and Demography, 1913, Government Printing Office:

"The particular periods when instincts appear have (in small part) been noted, and appropriate instruction has in the

main been provided, but the great failure of education today is its inability to recognize the fact (where it is absolutely essential that it should) that children differ in rapidity of development. Its maladjustments are particularly evident and distressing at or about the time of puberty. The change from an asexual to a sexual life may occur at any age from 6 to 20 years, usually between 12 and 15, but when it does occur, the changes are profound. In the short space of six months the child becomes a man or a woman, and the process is fraught with the dangers and turmoil of a new birth. There is an outburst of physical growth, 4 to 5 inches are added to height, 30 to 40 pounds to weight, and strength may be doubled in a short space of time. New mental abilities appear, while others disappear, the type of play changes, new companions are sought, new likings, tendencies, enthusiasms, and emotions make up the whole life. Old landmarks of life fade and new ones are eagerly sought.

"The sexual ripening determines an entirely new outlook upon life, the earning instinct looms large in the boy, and the home-making instinct in the girl.

"The important fact that is constantly disregarded is the fact that the pubertal change leaves the child a wholly different being - different mentally, physically, morally, and ethically from the children in the stage just left behind.

"This disregard results in the endeavor to teach classes that are composed of children of both prepubertal and postpubertal stages, the immature and the mature.

"Sitting alongside of each other, receiving the same teaching, subject to the same regulations and discipline, are children three or more years past puberty, and others three or more years lacking before the change will occur. The result is chaos. No one course of study can be fitted to their disparate needs, and no one form of discipline can be enforced with each group with equal success.

"This condition obtains in the whole of the grammar department of the elementary school, and in the first year of the high schools. It is particularly troublesome near the point of articulation of the two schools.

"The elementary school commences theoretically at or about the age of 6, when the child is able to go to and from school, and has become a burden at home, which the head of the home, the mother, can and should shift in part to the shoulders of the public. The lower school has for its opportunity the years up to the time when the child reaches its pubertal age. This is between the age (on an average) of 13 or 14; hence, allowing for slow progress, there will be about 7 or 8 years for the elementary school. From ages of experiment, it has

been found that the child will not study in school after this epoch has been reached unless undue compulsion has been used. The elementary school is naturally self-limited by the advent of puberty. The post-pubescent child is often kept in the elementary school by force of will and authority, and what is worse, he is subjected to the same treatment as the immature child."

1. Examples of adaption of principle studied, National Education Association, July, 1911: "A child's actual age should be determined by physio-psychological data."

2. The American Medical Association report on Committee on Medical Inspection recommends: "As far as practical, the grouping of children should be in accordance with developmental age."

3. The High School of Commerce arranged 8 sections of entering class from physiological age standpoint. The rate discharged from school was 35 per cent less than in the controlled group and 33 per cent less than the previous entering class.

4. Elementary Schools: 114 classes in 7th and 8th years in 7 schools were upon a physiological age basis. For example: 7A had most immature; 7AB, intermediate group; 7A3, most immature.

(A new plan of quickly and conveniently estimating physiological age was devised by the author, approximating the pubescence classification. It was based on observed correlations. A class of 40 can be examined by the author in 15 minutes, and assigned to physiological age groups. Teachers used the same method after brief instruction.)

"The boys formed a line and passed in review, each stating his age to the examiner. He was then given a number - one was most mature, five the least. The following signs were noted: The voice (changed and low or unchanged and high); the presence of the second molars; height and weight; the subcutaneous fat of the face and hands. In the immature the subcutaneous fat is more evident and adheres closely to the skin, which is of finer texture; in the mature the skin is firmer and thicker, less attached to subcutaneous tissues, which contain less fat. The prepubescent is chubby, the postpubescent may be fat, but there is an easily recognizable difference. This inspection is frankly different from the examination for pubescence, and the resulting classification may or may not differ from a division on the basis of that sign. It stands as a separate, but allied, experiment, and its results are regarded accordingly."

The following schedule is from the author's Fifth Annual Report as Director of Physical Training in the New York Public Schools, 1913. The opinion of the class teachers is as follows:

	Yes	Doubtful or no Change	No
1. Is there a more unified class consciousness?	107	1	6
2. If so, is this profitable to discipline?	93	3	17
3. If so, is this profitable to scholarship?	92	2	13
4. Is discipline harder?	25	19	65
5. Are the mature slower?	86	6	13
6. Are the immature "brighter"?	93	3	12
7. Do the mature work better segregated?	65	15	28
8. Do the immature work better segregated?	91	15	3
9. Is the approach to a subject different for immature and mature?	103	1	7
10. Are different methods indicated?	90	1	12
11. Do you think it worth while to make this grouping?	88	3	21
12. Comment.			

"The practical application of this doctrine will result in the removal of the immature from the high school, where they do not belong, and where their scholarship is poorer than the mature. They may be kept in a ninth year added to the elementary school. This will leave the high school to the mature alone.

"The mature should be removed from the elementary school and placed in subgrades added to the high school, or in an intermediate school, where their young adult possibilities may be fostered and find unimpeded development." (1944. Since this was written, the Junior High School has been developed. It helps somewhat. Author.)

SUMMARY

"There are in childhood and adolescence easily distinguishable epochs of development.

"Children of the same age but in different epochs may differ from each other 50 per cent in degree in certain characters and wholly in kind in certain other characters.

"There are certain easily recognizable signs which may guide us in distinguishing the different epochs of development.

"Children of wholly different developmental abilities are now taught by the same educational process. This is absurd and should be stopped.

"Every scientific study of children (particularly of those from 10 to 15 years of age) must contain reference to physiological age, and no scientific study is complete without such reference."

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STATEMENT OF C. WARD CRAMPTON, M.D., 1944:

With twenty years in health education and twenty-four more in the practice of medicine, the author has the good fortune to see and consider the end results of the educational process. He meets his high school pupils in high places and low after forty years.

He has watched the educational system with its movements of thought and practice, with both rejoicing and doubt; and has endeavored to aid adolescent interests. He helped organize the Boy Scouts, and has written a page on physical and total fitness for Boys Life for nearly a decade, has written an even dozen books on the subject, campaigned for health examinations and preventive medicine, organized and directed health service clinics and served on many commissions, committees, etc., etc., etc. In and out of season, he has watched, studied, taught, and directed work in this field, and as a physician has medically trained and coached men in living and has sought ways to mend damaged lives as they wax and wane by the decades. He centered much of his attention upon the adolescent, believing that more good or harm can be done in shortest time with less expending of labor and heart's devotion than at any other similar period between birth and death, with which the author is also familiar.

The author's interest lies much in decrescence and the amelioration of the aging process. In this, physiological age is even more important. "Bis pueri senes."

It is an unusual and much appreciated privilege accorded to the writer by our Editors to review some of his early and very earnest efforts to make clear physiological age and its importance.

He is commonly given credit for originating the term, "physiological age." This, I believe, properly belongs to the much respected and beloved Franz Boas, who, with G. Stanley Hall and Luther H. Gulick, gave the author the encouragement of their approval and interest.

No further recommendations are made. The record speaks for itself. It will not, cannot be changed. Today and tomorrow are still before us. Let us see what we can do. Deo juvante.

A STUDY OF THE GROWTH OF THE DYNAMIC CONCEPT OF KNOWLEDGE

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For the careful scientific investigator the conception that knowledge is not exact and static but approximate and changing does not require a lengthy explanation. Knowledge has its source in observations or measurements having greater or lesser variability. If repeated determinations are made at any given moment of the diameter of a cylinder, the strength of an electric current, or the reading ability of a child, it is well known that the successive measures will show some unreliability. That is, they will not duplicate each other exactly but will show a variability. Our knowledge of the diameter of the cylinder, the strength of the current, or the reading ability of the child, consists at its best of an average and its variation.

It is significant to note that the magnitude of the variability determines the extent to which we can predict the probable result when knowledge is used in planning a course of action. If the cylinder is to be supplied with a piston both cylinder and piston are machined to specified tolerances and then "fitted." It is recognized that measurements can be made only within limits and that one cannot predict exactly how the individual pieces will fit.

The relation of the approximate character of measures to the probable error in the predictions derived from those measures has been recognized in such fields as practical mechanics, and some of the more theoretical natural science fields. It has not been recognized, however, in the social area, especially in applied human and social relations. And it is in the social area that this problem is so important. For example, in the present state of knowledge there appears to be some relationship in young children between diet and tooth decay. It also appears that factors other than diet are involved in the production of caries. But what these factors are is not definitely known. An important one may be fluorine. But the relationships in the present state of our knowledge are not clear. If the parent wishes to produce good teeth in his children he cannot logically expect that careful control of diet will certainly assure that the child will have perfect teeth when he makes his first visit to the dentist. Neither can the dentist assume that be-

cause the child has many imperfections or cavities that the parent has neglected dietary principles. The parent may have been neglectful but before one can infer this from the conditions of the child's teeth the probable errors of the data expressing the relation of frequency and extent of caries to the food eaten must be considerably reduced.

Many of the data used in our everyday planning are based on observations rather than highly refined measurements. It is under such conditions that relatively large probable errors in plans must be anticipated and allowed for. How accurately, for example, can we predict whether a given method of organizing a community will have the results we desire, how many years it will take to pay off a mortgage on a farm, or how effective a given form of industrial organization will be? Yet in all of these, predictions are attempted almost daily.

The problem is further complicated. In almost any field, and in the social sciences particularly, the magnitude of the probable errors may vary rather widely from one portion of a field to another. At a given moment a field of knowledge may consist of some data (or generalizations derived from the data) having a relatively small probable error, and some having large probable errors. In addition there may be hypotheses, that is, statements of relationships that have not been tested.

The trained scientific investigator is also aware that changes in knowledge take place. Hypotheses may be subjected to test and changed into generalizations of known probable errors. More precise measuring instruments may be developed or more complete control of conditions may be achieved with the result that relatively unreliable generalizations are replaced by generalizations having a small probable error and so on. It is important to know that these changes may affect any or all portions of a field. They may be of all magnitudes. They may take place at all speeds.

Knowledge thus presents both a probability and a changing characteristic. Viewed at a given moment there is variability in measurement; viewed over a period of time there is change in degree of refinement.* To use knowledge in planning a course of action requires corresponding flexible and adaptive modes of behavior.

*These statements characterize knowledge as it has been developed. It does not take a position with respect to the philosophical problem as to whether there are exact laws. We may speculate whether there are such laws or not, but the only measurements that the race has been able to devise have some unreliability and the tests of any law are therefore only approximate.

In contrast to this requirement it may be noted that in our culture preference is given to relatively inflexible "rules of thumb." Man attempts to plan and control his world, especially his social world, by fixed regulations. There are traditions, codes, mores, laws. In all of these there is little that bears any resemblance to an adaptive interpretation or that takes account of the approximate and changing characteristics of knowledge.

The importance of such a dynamic conception of knowledge in the adaption to everyday problems has been suggested in papers by Ojemann (2), and Musgrove (1). There is strong reason to believe that possessing a working knowledge of the concept as it applies in human relations may help in resolving potential conflicts in the workaday world and thus influence development, especially the development of youth and adults. Fundamental to the studies of the role of the concept in human behavior, however, are methods of measurement and methods for controlling its development. The purpose of this paper is to report the results of a test designed to measure the various aspects of the concept in adolescents and to explore the relations between test scores and several variables that may affect its development.

The construction of the test presented a two-fold problem. On the one hand the concept itself may be subdivided into several aspects. On the other, the concept may be applied to all of the various fields of knowledge such as the physical sciences, the social area, the physiological field, etc. Conceivably in a given individual it may be well developed in some areas and not in others. For a thoroughgoing study the several aspects of the concept as they may be applied to the several different fields should be represented in the test.

In this study the concept was subdivided as indicated in Table 1, and items were constructed to cover the applications to physical, physiological, and mental-social areas. The figures in the table indicate the number of test items allotted to each subdivision of the concept and to each area. Even numbers are used throughout so that the test can be divided into two halves for studies of reliability. The total number of items comprising the test is 32.

Some examples of test items may be interesting and helpful to show the nature of the test.

To test the awareness of variability in measures:

Two men were measuring the strength of grip of a class of 8th grade pupils. Each pupil had three trials on each of two

TABLE 1

COMPOSITION OF TEST

Division of Concept	Area		
	Physical	Physiological	Mental-social
I. The Probability Characteristic			
a. Awareness of probable error of measures	2	2	2
b. Relation of error in prediction to error in fundamental data	2	2	2
II. Growth Characteristic			
a. Awareness of growth of knowledge	2	2	2
b. Understanding of method of growth			
1. Ineffectiveness of factors extraneous to research such as sheer lapse of time and individual prestige	2	4	2
2. Nature and function of research		6*	

* The six questions relating to research did not apply to any one area but rather to all areas.

successive days. Each time the person who read the scale was behind a screen so that he did not see the children. The conditions were about the same both days. For some of the children the average one day was as much as 2 lbs. higher than the day before and for several others the average was as much as 2 lbs. lower. Do you think:

(1) examiners can always read the scale exactly right but the children's strength of grip isn't always the same?
(2) some difference should be expected from one day to the next?
(3) they didn't get good measurements of those who weren't the same both days?
(4) they got exact measurements for those who were the same both days.
(5) the children were the same both days but the examiners read the scale wrong?

To test the awareness of error in predictions:

A man who found it necessary to budget his money carefully had kept a record for the past three years of how much it had cost him to heat his house during each one-year period. He also asked several of his friends who had similar homes how much it had cost them. In making an estimate of how much it will cost him during the coming year it would be most helpful to:

(1) take the average cost of the last three years of his home and allow for 15 per cent or more either way.
(2) average the cost for the past years from the different homes and plan on spending just that much.
(3) average the costs for his home only and allow just about that much.
(4) take the highest figure for the last three years of his home only and add 10 per cent for increase in price of coal which most people predicted to this man and then be absolutely sure of having allowed enough.
(5) average the cost of the last three years and allow just about 10 per cent more for any increase in price of coal.

To test the awareness of the growth of knowledge:

A father of two children aged one and three years read a very interesting book on astronomy. The book told in a simple and interesting way how our stars came to be, how the sun gets its heat and how old the earth is. Since this book is easy to read and understand, the father thinks it would be a good book

to keep so that he can have it for his children when they are about ten or twelve years of age. What do you think of the father's plan?

(1) It is a good idea to be thinking ahead as this father did and the plan of using the book is good.
(2) His plan isn't a good one because the book will certainly be far out-of-date in seven to nine years from now.
(3) His plan is a good one. There won't be any changes in a subject as old as astronomy.
(4) There may be a few changes in our knowledge of astronomy but all of the most important facts are known.
(5) There may be changes in a subject as old as astronomy and the father should think of this in his plan.

The 32 items were divided into two groups with the items in each set arranged in random order. The two sets were administered about a week apart. The subjects were 176 juniors and seniors in two midwest high schools.

A scoring key was prepared by administering the test to four persons who obviously possessed the knowledge implied in the concept and using only items to which all four agreed as to the responses. The test scores were then studied as to reliability and the relation of the growth of the concept to such variables as the number of science and mathematics subjects taken in school.

Since the two halves of the test were administered at two different times a reliability coefficient may be obtained by correlating the two separate sets of scores. Reliability can also be tested by correlating chance halves of each administration. These coefficients after the application of the Spearman-Brown formula varied from .72 - .79. A detailed study of the behavior of various items in the test indicates that by covering several aspects of the concept more comprehensively the reliability can be materially raised so that individual scores of relatively high reliability will be obtained. In this paper only group results will be reported.

One of the first questions in which the reader may be interested is that of the magnitude of the score achieved by high school juniors and seniors on a test of this kind. To what extent do they have a functional knowledge of this concept as measured by their ability to apply it to everyday problems. The mean score for the 176 subjects was $18.36 \pm .41$ and the range extended from 6 to 33. The mean score is approximately 50 per cent of the total possible score. When these results are viewed in the light of the fact that the test consisted of relatively simple applications to everyday problems it becomes clear that

a functional understanding of the concept is not developed to a very high degree in this group.

The reader may also be interested in the correlation of scores on this test with measures of intelligence. Intelligence test scores were available for 147 of the 176 subjects. Eighty-eight of these were Kuhlman-Anderson group test scores and the remaining 59, Otis scores. The correlation of test scores with I.Q. was .42 ± .07. Apparently the test does not measure to a very high degree that which is ordinarily measured by group intelligence tests.

It is also interesting to inquire how the development of the concept compares for the various areas, namely the physical, physiological, and mental-social fields. To make such a comparison it is necessary to express the scores in terms of per cent of total possible score since there is a slight difference in the number of items among the areas. The mean scores expressed in per cent of total possible score are as follows:

Physical area	43.4 ± 1.81
Physiological area	61.4 ± 1.39
Mental-Social area	43.8 ± 1.55

The difference between the scores for the physiological and physical areas as well as that between the physiological and mental-social areas is significant beyond the 1 per cent level. Just why this group of high school pupils should be more aware of the probability characteristics of knowledge in the physiological areas than in the mental-social or physical areas is not clear. An analysis of the test items does not give any reason to believe that the applications in the mental-social and physical areas were of a more abstract nature and there is, therefore, no a priori reason why one would expect a significantly higher score when applications are made to physiological problems. This point awaits further investigation.

The most interesting question, however, is the effect on the development of the concept of various educational experiences such as the nature and amount of training in mathematics and the number of semesters of science. The number of semesters of science taken by the subjects varied from zero to seven. Although the number of categories on this continuum is slightly limited, nevertheless it seemed more helpful to use coefficient correlations in expressing the relation between number of semesters of science and total score. This correlation was .07 ± .08. In other words no relationship between an understanding of the dynamic conception of knowledge as measured by the test and number of semesters of science is indicated.

The number of semesters of mathematics taken by the subjects ranged from two to seven, but since only one subject had taken seven semesters it was decided to use group comparisons. The subjects were divided into three groups: group one consisting of subjects who had two semesters of mathematics; group two, those having three or four semesters; and group three, those who have had five or more. After the subjects had been divided into the three groups, subjects from one group were matched with subjects from each of the other groups according to sex, grade in school, school attended, and I.Q. The detailed data are given in Table 2.

TABLE 2

SIGNIFICANCE OF DIFFERENCES BETWEEN TOTAL SCORES AND BETWEEN PHYSICAL SCORES FOR PAIRS MATCHED AS TO I.Q., SEX, GRADE, AND SCHOOL, BUT DIFFERING IN THE NUMBER OF SEMESTERS OF MATHEMATICS TAKEN

	Pairs N	d.f.	t	Sig. of diff. (per cent)
Total Score				
2 sem. vs. 5 sem. math.	10	9	.58	55
2 sem. vs. 3-4 sem. math.	31	30	.92	45
3-4 sem. vs. 5 sem. math.	13	12	.83	40
Physical Score				
2 sem. vs. 5 sem. math.	10	9	1.84	10
2 sem. vs. 3-4 sem. math.	31	30	.25	80

It will be seen that none of the differences is significant.

When the matched pairs were used to determine difference in scores on the physical area of the test the values of "t" were also insignificant. The data are given in the last two lines of Table 2.

Of the two variables studied, namely, number of semesters of science and number of semesters of mathematics, no relationship exists between these variables and test scores. These findings are significant. An understanding of the probability and growth characteristics of knowledge has important applications to everyday problems, nevertheless, the kind of training received by the adolescents at the present time in the areas most likely to influence the development of this concept seems to be relatively ineffective.

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In this paper the results obtained in an analysis of the growth of the dynamic conception of knowledge for a group of 176 high school juniors and seniors are presented. A test for measuring various aspects of the concept as it applies to physical, physiological, and mental-social problems is described. The reliability coefficient obtained by several methods varied from .72 to .79.

This group of high school juniors and seniors obtained a score in the neighborhood of 50 per cent of the total possible score. Since the test items were constructed by using everyday situations it is apparent that the development of the concept had not proceeded very far in this group.

When the applications of the concept to the three areas, physical, physiological, and mental-social were compared, a significantly greater development in applications to the physiological area was found. The physical and mental-social areas were about equal in terms of total possible score, but the development in the physiological area was significantly higher. The cause for this difference is not at present apparent.

The amount of training in courses that might be expected to influence the development of this concept, namely, the number of semesters of science and number of semesters of mathematics, did not yield significant correlations. The correlation coefficient between number of semesters of science and total score was $.07 \pm .08$. Matched pairs yielded no significant differences when compared in terms of number of semesters of mathematics taken.

Since the number of subjects achieving 75 per cent or more of a total possible score is very small, the next step in this series of investigations seems to be to develop experiences which will accelerate the development of the concept so as to make possible studies of the effect of the concept on behavior and personality development.

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SEX DIFFERENCES IN SOCIAL SUCCESS AND PERSONALITY TRAITS

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Sex differences have been the subject of many psychological investigations. Most of the earlier studies were concerned with sex differences in intelligence, academic achievement, and interests. During recent years more attention has been paid to differences in social success and personal traits. The present study is concerned with problems in these areas. The data reported are concerned with answering the following questions:

1. Are there significant sex differences in popularity as determined by pupil choices?
2. Are there significant sex differences in pupil choices of best friends and best leaders for the school year?
3. Are there significant sex differences in twenty personal traits as determined by composite scores based on pupil and teacher ratings combined?
4. Are there significant sex differences in personal traits between most popular boys and most popular girls?
5. Are there significant sex differences in twenty personal traits on the basis of teacher ratings alone?
6. Are there significant sex differences in self ratings on the California Test of Personality?

The subjects used were pupils in three fourth grades in three schools in Denton, Texas. One of the schools utilized is the Demonstration School associated with North Texas State Teachers College; the other two are public schools. All data were collected during the school year 1941-42.

It will be appropriate first to describe the methods of gathering the data.

As stated above, popularity or social acceptance was determined by pupil choices. The choosing situations used in

*The writer wishes to express his appreciation to the school officials and teachers of Denton who have given their wholehearted cooperation in this study. These include: Superintendent, R. C. Patterson, Dr. J. C. Matthews, Mr. J. L. Yarbrough, Mr. Morris Wallace, Mrs. Lulu Shumaker, Mrs. R. N. Lukens, and Miss Ethel Miller.

the three schools for this purpose are listed below:

In the Demonstration School:

October, choosing ones preferred as working companions on committees which were to be appointed for the semester.
December, listing names of all those to whom Christmas presents would be given if it were possible to do so.
February, listing names of those to whom Valentines were to be given, in order that the teacher would know how many sheets of colored paper to give to each child for making the Valentines.
March, names of three friends were written on rating sheets which were then used to rate the friends on twenty personal traits.
April, selecting companions for making an arithmetic chart, and also for working on a sign reading project.
May, listing names of all best friends throughout the school year, as well as the names of all the best leaders in the room during the school year.

In the Sam Houston School:

November, listing names of all children who would be selected to remain in the room if all others had to leave.
December, designating names of those to whom Christmas presents were to be given, as well as names of those to whom presents would be given if it were possible to do so.
February 10, voting on the king and queen for a Valentine party.
February 14, determining the number of Valentines each child received. This was done by taking the Valentines out of the box and counting the number for each child before they were distributed to the children.
March, same as for School A.
May, same as for School A for both friends and leaders.

In the Robert E. Lee School:

November, voting for officers in a class club.
December, same as for November, with all officers available for re-election.
February, counting of Valentines as in School B.

March, same as in Schools A and B.
April, election of club officers.
May, voting on the "best citizen" in the room for the school year. Considerable emphasis had been given to citizenship and five or six votings had been held throughout the year on the "best citizen."
Same as for Schools A and B for both friends and leaders.

In nearly all of the above situations there was no limit placed on the number of choices which could be made. This technique provides a more adequate measure of each child's social acceptance than is possible when choices are limited to only one, two, or three names. All the choosing situations were conducted by the classroom teacher.

In order to state general social acceptance or popularity in numerical terms the following system of scoring was used: first choice - 5 points, second - 4 points, third - 3 points, fourth - 2 points, fifth - 1 point, and all other choices - 1 point. (This point system was not used in the situation involving the giving of Valentines, since no order of choice was indicated. Each Valentine counted two points.) The composite social acceptance score for each child was determined by converting his raw score in each choosing situation into a per cent, adding all his per cent scores, and then obtaining an average for each child. For example, one child in Demonstration School received the following series of per cent scores in the eight choosing situations throughout the school year: 4.5, 1.3, 6, 1, .6, 2.2, 4.9, and 8.9. This makes a total of 29.6. When this number was divided by eight, an average of 3.7 was obtained. This was the child's final social acceptance score for the year. All the other children had similar scores which ranged from .37 to 12. The total scores for the children in the other two grades were obtained in the same manner, and since all scores were turned to per cents, the results for the three schools could be thrown together and subdivided into quartiles for comparative purposes.

The California Test of Personality - Elementary, Form A was administered to the children in the month of March, 1942. The children had no difficulty in answering the questions, with the exception of those who were very poor readers. These had to be helped individually by reading the questions to them.

The scale used to obtain the trait ratings was a slight modification of the scale developed by Caroline McCann Tryon in connection with the Growth Study of Adolescents of the University of California Institute of Child Welfare (13). Some changes were made in the wording in order to make the descriptions of the traits more suitable for fourth grade children. The

scale is composed of twenty traits each of which is paired with its opposite. Also each is accompanied by a sub-statement which makes its meaning more clear. Below are three examples taken for the scale.

Is Like This:	About Average	Is Like This:
Restless: finds it hard to sit still in class; and he moves around in his seat or gets up and walks around.		Quiet: can work very quietly without moving around in his seat.

Is Like This:	About Average	Is Like This:
Fights: enjoys a fight.		Avoids Fights: never fights but lets the other person have his own way.

Is Like This:	About Average	Is Like This:
Enthusiastic: always seems to have a good time; seems to enjoy everything everybody does no matter where it is - in school, on the playground, at a party, everywhere		Listless: never seems to have a good time; never seems to enjoy very much anything he does.

Since all the other traits are listed in subsequent tables they need not be given at this point.

The children had no difficulty in following this scale with the exception again of those who were very poor readers. Individual help was given to these as in the case of those who could not read the Personality Test.

All the children were given three copies of the scale and were told to rate three other pupils whom they regarded as friends in their room at school. Since children vary greatly in popularity, some were rated by eight or nine other pupils, and in one case by eleven others. Also a few children were not rated at all, since no one chose them as friends. In order to get ratings on all children, the names of those who received no

ratings, or only one or two, were written on copies of the scale, and these were distributed to the pupils in each room with the direction to make the ratings as best they could. Some attempt was made to have a child rated by another one whom the teacher considered to be his friend, but in many cases this was not possible. However, the fact that the two children were not personal friends probably should not be considered a serious matter in the validity of the ratings, since in almost every case both children had been together in the same grade for more than one semester and in most cases for more than three years. No child was included in the ratings who had been in the group less than six weeks. Furthermore, not more than 20 per cent of the children in any grade were involved in the assigned ratings.

After the children had completed their ratings, each of the classroom teachers rated all their pupils on the same scale. The teachers did not know how the children had rated each other when they made their own.

After the data from the rating scales were tabulated, a system of scoring was utilized to arrive at a total score for each child. This system was as follows:

Marked degree of given trait	5
Above average of given trait	4
Average amount of given trait	3
Below average of given trait	2
Marked absence of given trait	1

These different degrees were defined as follows:

1. Marked Degree - Three or more pupils agreed 100 per cent and the teacher agreed with the pupils.
2. Above Average - Sixty per cent or more of the pupils (but not 100 per cent) agreed and the teacher agreed with the pupils; three or more pupil raters agreed 100 per cent but the teacher disagreed, or rated the child as average.
3. Average - The pupils were divided (anything less than 100 per cent agreement) and the teacher rated the child as average, or disagreed with the predominant rating of the pupils.
4. Below Average - Same standards as for "above average" except for opposite trait in each pair.
5. Marked Absence - Same standard as for "marked degree" except for opposite trait in each pair.

In those instances in which the pupil raters were evenly divided, the scales were tipped in the direction of the teacher's

rating.

Although the most typical number of child raters for each pupil was three, better than a third of the population in each grade had four or more pupil ratings upon which their composite score could be based. Approximately 10 per cent had six or more ratings. With this many raters, together with the rating of the teacher, upon which to base the score for each trait, it would seem that the measures obtained should be regarded as having a high degree of validity.

Attention will now be given to the first question of this study: Are there significant sex differences in popularity as determined be pupil choices? The facts bearing on this question are given in Table 1.

TABLE 1

NUMBER AND PER CENT OF BOYS AND GIRLS REPRESENTED IN QUARTILES BASED ON SOCIAL ACCEPTANCE SCORES

Quartiles	No. of Boys	Per Cent of Boys	No. of Girls	Per Cent of Girls	Diff. in Favor of Girls
4	9	22.5	13	28	5.5
3	9	22.5	12	26	3.5
2	11	27.5	10	22	-5.5
1	11	27.5	11	24	-3.5

A brief examination of Table 1 reveals that the girls are represented in the two upper quartiles to a greater extent than the boys, and that the opposite is true in the two lower quartiles. The data show that there are 5.5 per cent more of the total number of girls than of boys in the highest popularity quartile. A higher proportion of girls is also found in the third quartile, and, of course, it would naturally follow that the boys have higher proportions in the two groups below average in social acceptance. The question may be asked: Are these differences large enough to be considered significant? Probably a conservative opinion would be that they are not. However, it is necessary to consider more of the data available from the study before making a more thorough evaluation.

In Table 2 the boys and girls are compared as total groups (see next page).

TABLE 2

SEX DIFFERENCES IN SOCIAL ACCEPTANCE SCORES BY PUPIL CHOICES

Sexes	No.	Mean	Range	Sigma	σm	σd	Diff.	C.R.
Boys	40	3.24	10.86-.37	2.67	.42	.60	.57	.95
Girls	46	3.81	12.00-.00	3.06	.44			

A brief study of Table 2 shows that the girls have a slightly higher mean than the boys, and are a little more variable on the basis of both range and standard deviation. However, it can be observed that the critical ratio is far below the standard for statistical reliability. Consequently, it must be concluded that although the girls in the groups studied were slightly superior to the boys in social acceptance, there is very little assurance that this difference would hold true in other similar samples.

The second question of this study bears a close relation to the above data. Are there significant differences between the sexes in pupil choices of best friends and best leaders for the school year? This question is answered in Table 3.

TABLE 3

SEX DIFFERENCES ON CHOICES OF BEST FRIENDS AND BEST LEADERS FOR SCHOOL YEAR 40 BOYS AND 43 GIRLS

Sexes	Best Friends				Best Leaders			
	Mean	Md.	Per Cent Zero Scores	Range	Mean	Md.	Per Cent Zero Scores	Range
Boys	3.37	2.1	23	0-19	3.57	1.0	35	0-19
Girls	3.68	3.3	16	0-19	3.64	1.1	35	0-17

A number of facts are evident from Table 3. The girls have slightly higher means than the boys for both friends and leaders. (The differences are too small to warrant statistical treatment.) The median for the girls in "best friends" is definitely higher than that for the boys, but there is no difference in medians for "best leaders." The girls have 7 per cent less zero scores

than the boys in "best friends," but the per cents are the same for "best leaders." The sexes show practically the same range in both measurements.

It is apparent from the above facts that the girls have a slight superiority over the boys in the voting for "best friends," but that there is no sex difference in the voting for "best leaders."

The rather small differences found in this study between the sexes in social success is at variance with results previously published on most of these same subjects when they were in the second and third grades (1, 2). In these earlier grade levels the girls showed a rather marked superiority over boys in both general social acceptance and in number of mutual friends. There is not sufficient data from this study, or from others elsewhere, to know whether there are any typical changes which take place in the relative social success of boys and girls as they pass through the elementary school. The present data are only suggestive of the possibility that boys may attain a better social status as they go beyond the third grade. It is known that girls mature more rapidly than boys and that this rate of maturity slows down with age. This fact might have some bearing on the above findings.

Attention will now be turned to a consideration of sex differences in personality traits. Are there any differences between boys and girls in personal traits which are important to parents and educators? The data of this study bear on this question, first, from the standpoint of the composite scores which were obtained from a combination of pupil and teacher ratings on twenty personal traits. The determination of these scores has been previously described. Table 4 summarizes the trait differences between the sexes.

A review of Table 4 shows that in only two of the twenty traits is there a completely reliable difference between the sexes. These two are "restless" and "fights," and in both traits the boys have the higher scores. There are three other traits, however, which show differences that are almost completely reliable, since the critical ratios are all 2.5 or better. These three are "tidy," "happy," and "at ease with adults." All these differences are in favor of girls. These two sets of results complement each other in emphasizing the energetic, aggressive traits of boys as contrasted with the more quiet, conforming traits of girls.

In order to check further on sex differences in personality, the twenty most popular boys were compared with the twenty most popular girls. In nearly all the traits the differences were very small, but there was a striking corroboration of the results given in Table 3 in that the boys again were shown to have

TABLE 4

AVERAGE SEX DIFFERENCES IN TWENTY PERSONAL TRAITS BASED ON COMPOSITE SCORES FROM PUPIL AND TEACHER RATINGS

Sexes	Number	Restless	Talkative	Attention Getting	Bossy	Tidy	Fights	Daring	Leader	Active In Games	Sense of Humor	Friendly	Welcomed	Good Looking	Enthusiastic	Happy	Laughter - Jokes	At Ease with Adults	Active In Recitations	Grownup	Older Friends
Boys	37	2.6	3.0	2.6	2.1	3.8	3.0	3.7	3.0	4.1	3.9	3.9	3.9	3.7	3.8	4.0	3.7	3.4	3.7	3.3	3.8
Girls	42	1.8	2.7	2.4	2.0	4.3	2.1	3.3	3.3	3.9	3.7	4.0	4.0	3.7	4.2	4.4	3.7	3.8	3.8	3.3	3.5
C.R.*		3.5	1.7	1.3	1.0	2.5	3.6	2.0	2.0	1.0	1.5	.7	.7	0	2.0	2.7	0	2.7	.6	0	2.0

* Critical ratios were obtained by dividing the mean differences between the sexes in the twenty traits by the standard error of these differences.

reliably higher averages in "restless" and "fights." The boys had an average of 2.50 in fighting as compared with only 1.56 for the girls. The critical ratio of the differences was 11. The average for the boys in "fights" was 3.0 as compared with 2.0 for the girls. The critical ratio of the difference was 12.5. These marked differences show that popular boys are much more likely to be characterized by overt activity and aggressiveness than are popular girls. This conclusion is reinforced by the findings from the study of adolescents by Tryon previously cited. Two of the traits found by her to be generally approved for twelve-year-old boys and not approved for twelve-year-old girls were "restless" and "fights" (13, p. 60).

May not the above findings be interpreted to mean that a school in which popular boys feel at home must be one which allows sufficient leeway for energetic activity, social aggressiveness, and even some fighting - at least of a mild sort? Also do not the above findings mean that if boys and girls are to be educated together - and the writer believes that they should be - that some differences should be allowed in the kind of behavior standards expected of the two sexes? Should not parents and teachers encourage boys to be aggressive in socially constructive ways in order to promote their popularity? Should Sunday School teachers teach boys that they should never fight but should, instead, "turn the other cheek?" And what about severe disciplinary control which causes most of the more timid boys to suppress what little aggressiveness they have? Studies on psychological sex differences should be of value to parents and teachers in emphasizing the importance of educating boys to play the most approved masculine role, and of educating girls to play the most approved feminine role in our society.

The fifth question with which this study deals bears closely upon the preceding findings and remarks. This question is: When the teacher ratings on the twenty personal traits are taken separately from those of the pupils' ratings, what sex differences are evident? Do they agree with those from the composite scores? Table 5 gives the teacher ratings.

Table 5 shows only the high positive ratings given by the teachers, that is, checks at the extreme left of the scale. The remaining percentages for each trait were not all at the opposite end of the scale, since there were a good many average ratings. It was thought, however, that these average ratings probably represented a rather high degree of uncertainty on the part of the teachers and therefore would be less significant.

A brief examination of the differences in Table 5 shows that the greatest sex differences, as observed by the teachers, are in the following traits: tidy, fights, good looking, enthusias-

TABLE 5

SEX DIFFERENCES IN TEACHER RATINGS ON TWENTY PERSONALITY TRAITS
(ALL FIGURES IN PER CENTS)

Sexes	Number	Restless	Talkative	Attention Getting	Bossy	Tidy	Fights	Darling	Leader	Active in Games	Sense of Humor	Friendly	Welcomed	Good Looking	Enthusiastic	Happy	Laughter - Jokes	At Ease with Adults	Active in Recitations	Grownup	Older Friends
Boys	37	11	35	16	16	65	24	40	27	65	48	46	46	35	78	56	29	43	43	24	48
Girls	42	12	31	24	16	91	10	39	39	58	53	56	46	51	56	63	42	51	51	46	48
Difference in favor of girls		1	-4	8	0	26	-14	-1	12	-7	5	10	0	16	-22	7	13	8	8	22	0

tic, and grownup. The percentages are in favor of the girls in the traits of tidy, good looking, and grownup. The first two of these three traits show that the girls are upholding their reputation as the "fair sex." The third is particularly interesting in view of the fact that girls are known to mature more rapidly than boys.

The 14 per cent higher rating for boys in "fights" corroborates the finding on this point from the composite scores given in Table 4. There would seem to be little room for doubt but that this is a true sex difference in the groups studied, and presumably in other similar populations.

The finding in Table 4 that the boys were reliably more restless than girls is not borne out from the teacher ratings alone. It may be that the pupils were in a better position to observe this trait than the teachers, since they were in closer contact with each other.

The 22 per cent higher rating in enthusiasm given to the boys by the teachers is also at variance with the composite scores, since on the latter the girls had a little higher average in this trait. It is possible that this difference is due to enthusiasm being a hard trait to rate, since it is rather broad in its meaning, even with the descriptions given on the scale. It is also possible, however, that the kind of energetic activity which the children viewed as "restlessness" was viewed by the teachers as "enthusiasm."

It is again noteworthy that by and large the differences between the sexes in the twenty personal traits are not great, although it is still true that the girls have an edge over the boys in nearly all traits which have the most direct bearing on success in inter-personal relationships as: tidy, leadership, friendly, good looking, and laughter and joking. Being "welcomed" shows no sex difference.

The final question of this study has to do with sex differences in personal traits as revealed by self-ratings on the California Personality Test. Table 6 gives the findings on this question.

The data of Table 6 reveal the following facts: The girls are superior to the boys in every aspect of the scale except two (C and E), there is an appreciable difference between the sexes in only one trait (social skills), but the differences approach statistical reliability in five other traits, namely, Total Self-Adjustment, Self-Reliance, Sense of Personal Worth, Community Relations, and Total Adjustment. All the critical ratios for these last five measurements are 2 or better.

It is certainly significant that the self ratings are in line with results from the pupil choices in showing that the girls have an edge over the boys in attaining desirable personality

TABLE 6

SEX DIFFERENCES ON THE CALIFORNIA TEST OF PERSONALITY - ELEMENTARY, FORM A
38 BOYS AND 44 GIRLS

Divisions of the test	Mean		Mean Diff. in Favor of Girls	Sigma		Diff. / σ d (C.R.)
	Boys	Girls		Boys	Girls	
1. Total Self Adjustment	47.2	56.5	9.3	19.5	20.8	2.07
A. Self Reliance	62.2	72.8	10.6	22.2	23.4	2.00
B. Sense of Personal Worth	54.3	65.8	11.5	26.0	24.4	2.00
C. Sense of Personal Freedom	40.4	40.3	-.1	24.2	18.5	.08
D. Feeling of Belonging	58.4	58.9	.5	26.6	28.0	.08
E. Withdrawing Tendencies (Freedom from)	45.1	44.2	-.9	20.4	31.6	.13
F. Nervous Symptoms (Freedom from)	37.6	47.4	9.8	30.4	26.7	1.50
2. Total Social Adjustment	45.9	53.6	7.7	24.7	26.2	1.40
A. Social Standards	48.1	54.6	6.5	29.4	25.9	1.07
B. Social Skills	47.0	64.0	17.0	23.4	20.8	3.39
C. Anti-Social Tendencies (Freedom from)	47.0	55.8	8.8	26.5	26.9	1.49
D. Family Relations	49.6	61.1	11.6	29.9	30.8	1.73
E. School Relations	42.3	55.0	12.7	29.0	30.0	1.89
F. Community Relations	47.7	65.4	17.7	34.0	27.0	2.60
Total Adjustment	47.1	57.4	10.8	21.2	22.2	2.25

traits and social skills. It is true that many of these differences are small, and even slight in some instances, but still the differences are there with a high degree of consistency.

The two differences in Table 6 which are in favor of boys are too slight to be of any consequence. It is interesting to note, however, the similarity between these two traits and the two found to show the greatest difference between the sexes in

Table 4, namely, "restless" and "fights." A sense of personal freedom and the absence of withdrawing tendencies bear a close relation to the active and aggressive characteristics of restlessness and fighting.

It is particularly noteworthy that the one trait on the self-rating scale which showed a completely reliable difference of girls over boys was "social skills." Here is testimony from the boys themselves that they feel inadequate in social relationships as compared with girls. Such testimony, especially when corroborated by other sources of evidence, should be taken seriously by parents and educators.

Is it not possible to see a relation between the findings of this study on sex differences in personality traits and certain persistent problems which adults have in managing boys, particularly in institutions such as the church, and the school. It has long been recognized that boys are more difficult to manage than girls. Disciplinary records in schools are proof of this as well as statistics on delinquency which show a much larger proportion of boys over girls. Also teachers generally rate girls as having more favorable personality traits than boys. Some studies have shown that girls make consistently higher grade averages than boys throughout the school system (8, 12). Also more boys drop out of school. The seriousness of this latter fact is noted by Englehardt and Overn in their Secondary Education Principles and Practices (p. 17) when, after reviewing some figures on the relative proportion of the sexes graduating from high schools, they say: "Only as one reflects on the data does the full significance appear. Those responsible for education are confronted with a serious problem when the proportion of boys graduating from high schools is as small as it appears in many of the public schools." It is a matter of common observation that girls stay in churches to a much larger extent than do boys.

Aside from other factors which are known to be operating, is it not possible that one reason why boys drop out of churches, schools, and even homes faster than girls do, is that many of these basic institutions are not well adapted to typical masculine traits. It seems to be true, particularly in respect to schools, that when greater provision is made for the expression of aggressive traits, the boys do stay in school longer and offer much less difficulty in the way of control. Provision for the expression of aggressive traits in schools has been attained chiefly through a more liberal type of administrative control, student participation in school management, athletics, other forms of extra-curricular activities, and the allowance of more student initiative in regular class work. Of course, girls as well as boys

have participated in all these things, but it seems true, nevertheless, from the studies on sex differences, that such policies and activities are more necessary in the education of boys than of girls. It is interesting to note a corroboration of this point in a study by Landreth on crying among children of nursery school age (9). Although not much difference was found between the sexes in amount of crying at the nursery school, a considerably higher incidence of crying among boys was found in the children's homes. The author concludes that it is possible that boys of the socio-economic group studied "are more irked than girls by complying with routines and parental restrictions of activity." The author refers to Goodenough's findings on negativism in nursery school children as supporting this view.

The small but consistent superiority of girls over boys in scores on the social acceptance tests as well as on the California Personality Test should be a stimulus to parents and teachers to reconsider their programs for the socialization of boys. Although it is true that only on the Social Skills section of the California test was a highly reliable difference obtained, still the consistency of the girls' superiority should not be overlooked. Furthermore, as previously stated, the girls in this follow-up study have shown considerably greater superiority over the boys in social success in the two preceding school years. The possibility of a real sex difference in ease of socialization, as well as in the kind of social control best adapted to promoting personality development, should not be lightly dismissed, any more than it should be accepted without sufficient evidence. Certainly there are many homes, churches, and schools that have made marked progress in the last twenty-five years in making better provision for the needs of both boys and girls, but it is equally certain that many others have not. This is obviously a large problem with many phases to it. The only contribution of the present study to this problem is in emphasizing the need, on the part of adult leaders of children, of being more concerned about developing social skills in boys, and of instituting a type of social control which will allow constructive expression of aggressive traits. When boys do not acquire facility in social skills they feel inferior and are likely to compensate in some socially disapproved ways; when their normal aggressive impulses are denied expression their typical response is either to fight back in some way or to leave the situation - whether it be home, church, or school.

SUMMARY

Social success in three groups of fourth grade children was determined by pupil choices. Ratings on personal traits were obtained from pupils and teachers. Self-ratings were obtained from the California Test of Personality - Elementary, Form A.

On the whole, sex differences in social success and in personal traits were not found to be large, but there was a high degree of consistency in favor of girls on both kinds of measurements. In only two traits were highly reliable sex differences found. These traits were "restless" and "fights," and the boys had the higher scores. These two traits were also the only ones in which the most popular boys had reliably higher averages than the most popular girls. Also on the basis of teacher ratings taken separately from the pupil ratings, the boys were given a 14 per cent higher average than the girls in "fighting." The teacher ratings gave the girls markedly higher averages in being tidy, good looking, and grownup. On the California Test of Personality the girls had a higher mean score on Total Adjustment and on all subdivisions of the scale except two, but complete statistical reliability was found on only one part of the test. This was on "social skills," and the advantage was with the girls.

Some relationships between these findings and the education of boys and girls were pointed out.

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SICKNESS ABSENTEEISM AMONG WHITE SCHOOL CHILDREN IN HAGERSTOWN, MARYLAND, 1940-43

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To gauge accurately and with timeliness the changes occurring in health conditions is always important, but never more than at present when the civilian population must be maintained at a high level of efficiency in the face of a curtailment of civilian medical resources. Sickness and death rates among children constitute sensitive indices of a population's health level. The sickness rates in particular are useful since they reflect conditions which can be deleterious to the well-being of the population even though they are not fatal. Because of the value of such information, monthly data have been collected on school absences due to sickness among the white children of Hagerstown, Maryland, since October 1940. A three-year record, covering the school years 1940-41, 1941-42, and 1942-43, is presented here. For the year 1941-42 it was necessary to terminate the project by March 1st because of decrease in personnel.

Absenteeism among the school children of Hagerstown has been studied off and on for some twenty years by the U. S. Public Health Service. This city was selected in 1921 for one of the first morbidity surveys in the country because it was considered a typical community, neither completely industrial nor completely agricultural, and having in addition a high proportion of stable American-born stock. Studies pertaining to other aspects of public health have been continued there since, for this same reason and especially because the civic and school authorities, the health department, and the population itself have all demonstrated a high and unusual degree of cooperation. A preliminary comparison with earlier data has already appeared (1).

The particular value of the observations made in this community is that information is at hand to weigh the significance of changes in terms of a mass of data extending back over many years. Thus, changes which occur may be properly evaluated in terms of the experience of the past and of all the information available about the children and their families.

The war has affected Hagerstown because of its important industry but it has not become a war-boom area. The population between 1940 and 1943 has increased from 32,500 to 40,000. Its prewar physician population of 44 has decreased by 10, bringing the number of persons per physician from 740 to 1,175.

CHILD DEVELOPMENT

Material and Method

A record of absences by cause has been collected on all the white school children of Hagerstown for various periods since 1921 (1, 2). The technique employed is briefly this: Children who are absent for any length of time present to their teacher an excuse slip containing among other items the reason for their absence. Where the reason is sickness, certain pertinent questions are to be answered - the cause of the sickness, its duration, and whether or not a physician was called. Whenever it appears warranted, a check is made with the physician to learn the precise diagnosis. These slips are collected and tabulated monthly.

In this paper the amount of sickness is measured by the number of days absent because of sickness per 100 children-school days. For any specific cause the formula is:

$$\frac{\text{Days absent in month for specific cause} \times 100}{\text{Children enrolled} \times \text{number of school days in month}}$$

The rates for all ages combined have been adjusted to the age distribution of the children attending Hagerstown schools in 1940-41. This adjustment is made by 1) calculating the age specific rate for the years following 1940-41, 2) multiplying each age specific rate by the proportion of children in that age group in 1940-41, and 3) summing these products to get the adjusted rate for all ages combined.

In Table 1 are shown the average monthly school enrollment and the average monthly number of children-school days, or days of exposure. It will be observed that the data are based on some 6,500 children and a school month of about 20 days.

Sicknesses which result in absence from school do not lend themselves to precise diagnostic classification and, for the more frequent causes of absence, physicians or nurses are not consulted by the parents. The causes of illness, therefore, can only be described in broad groups, and it has been found best to deal with only five principal categories. The first group is "colds." The second group is made up of the more definite types of respiratory conditions; these are classified as "other respiratory" and include grippe, influenza, pneumonia, bronchitis, etc. The third, "digestive," is for the main part composed of the indefinite gastro-intestinal disturbances to which children as well as adults are prone. The fourth category is "headaches," which is a rather important if somewhat vague cause of absence due to sickness. In the fifth category, "other sickness," are included the major communicable diseases which affect children:

TABLE 1

ATTENDANCE IN HAGERSTOWN, MARYLAND SCHOOLS IN A THREE-YEAR PERIOD* (WHITE CHILDREN ONLY)

Age (years last birthday)	Average number of children			Average monthly number of children-school days		
	1940-41	1941-42	1942-43	1940-41	1941-42	1942-43
All ages	6,505	6,669	6,507	134,675	127,391	130,930
Under 7	1,459	1,413	1,528	30,270	26,982	30,748
8 and 9	1,092	1,102	1,086	22,412	21,055	21,858
10 and 11	1,114	1,133	1,218	23,116	21,638	24,517
12 and 13	1,233	1,305	1,241	25,579	24,938	24,976
14 and over	1,607	1,716	1,434	33,298	32,778	28,831

*Based on the months October through May for 1940-41 and 1942-43, and October through February for 1941-42.

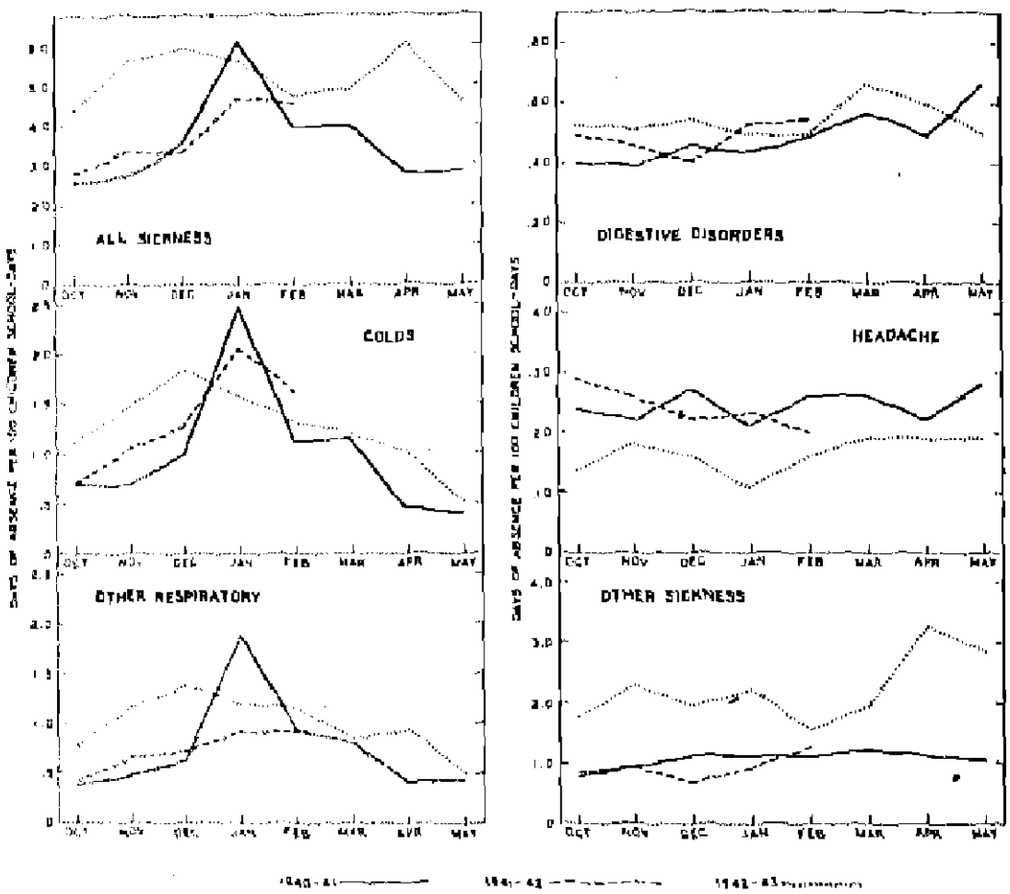

Figure 1. Days of absence due to sickness per 100 children-school days, from all causes and certain broad groups of causes - Hagerstown white school children, 1940-43.

chickenpox, mumps, measles, as well as a miscellany of conditions not covered elsewhere.

The findings are summarized in Figure 1 which consists of a set of sub-figures, one for all sickness combined, and one for each of the groups of illnesses specified above. The data for the three school-years covered are superimposed one upon the other to facilitate comparisons and to bring out the factors common to all the school years studied.

Rates 1940-1943

All Sickness. It is well known that in this climate more sicknesses occur during the winter months than at any other season of the year. Confirmation is lent by the data on all sickness. In 1940-41 the rate started from a low of 2.6 days of absence per 100 children-school days in October, rose to a peak of 6.1 in January, and fell again with some regularity to a rate of 2.8 for May. The same general pattern is seen for the available period of 1941-42, although the January peak was much lower than that for the year previous. In 1942-43 the pattern differed markedly, the absence rate being higher in general. Two peaks are to be noted, one in December and the other in April, with respectively 5.9 and 6.0 days of absence per 100 children-school days. The low points occurred in October, February and May. The significance of these variations will appear in the discussion of the specific groups of causes.

Colds. Colds are by far the greatest single cause of school absence due to illness. Their effect on the all sickness rate is readily observed in the similarity between the figures for colds and for all sickness (except for the Spring of 1943). In general, colds are the reason for between a fourth and a third of all days of absence due to illness. In the peak months (January, 1941 and 1942), colds accounted for over 40 per cent of all days of illness-absence. The peak in January 1941 was also associated with an outbreak of mild influenza which took place at that time. Comparison of the three years shows that the year 1942-43 differs from the two previous years in that the peak was not in January but came a month earlier.

Other Respiratory. In general, other respiratory diseases (grippe, influenza, tonsillitis, sore throat, etc.), when their absence rates are combined, follow the sickness pattern shown by colds. However, only the 1940-41 observations display a definite peak, due largely to the outbreak of influenza which occurred during the winter of that year. The 1942-43 data show a light rise in December but this is apparently of no great significance.

Digestive Disorders. Digestive diseases are another serious cause of absence from school. The incidence of these disorders is higher in the terminal months of the school year although no marked seasonal variation is noted. No uniform differences among the three years are to be found except for some tendency in the 1942-43 rates to be higher than those in 1940-41. However, the differences are not statistically significant.

Headaches. Headaches show only slight seasonal variation. In both the 1940-41 and 1942-43 school years, a low point was reached in January. This and the fact that the rates in 1942-43 were consistently lower than those in the other two years, suggest the existence of some kind of inverse relationship between headaches and colds, in the sense that when colds are prevalent, they furnish a more urgent excuse for absence for those children prone to headaches.

Other Sickness. The absence rates for all other causes of sickness show no regular seasonal variation as such; peaks in the curve can usually be traced to outbreaks of some communicable disease. The year 1942-43 experienced absence rates twice as high as those in the preceding two years. The extremely high peak in April 1943 was the result of an outbreak of measles; the smaller peaks in November 1942 and January 1943 were largely brought about by outbreaks of mumps and chickenpox.

Other Absences. It is important to examine the absences due to causes other than sickness since they reveal trends concerned with social and economic factors which bear on absenteeism in general. The year 1942-43 was marked by a large increase in absences supposedly not due to illness, the rates ranging from 1.8 to 2.9 days of absence per 100 children-school days as compared with a range of 1.4 to 2.1 in 1940-41 (figure not shown). Two peaks were noted in 1942-43, one in December and one in April. These peaks may be associated with attempts on the part of the parents to prevent infection of the children during outbreaks of the contagious diseases mentioned, but this cannot be stated with any degree of certainty.

Conclusion

In general, it is difficult to discern any definite trend with regard to increase or decrease of absences due to illness during the three years examined when the individual groups of illnesses are studied. The year 1942-43 was marked by outbreaks of three communicable diseases frequent among children. These may have affected absenteeism caused by the other conditions discussed. In 1941-42 and the following school year there occurred outbreaks of upper respiratory infection. This was not

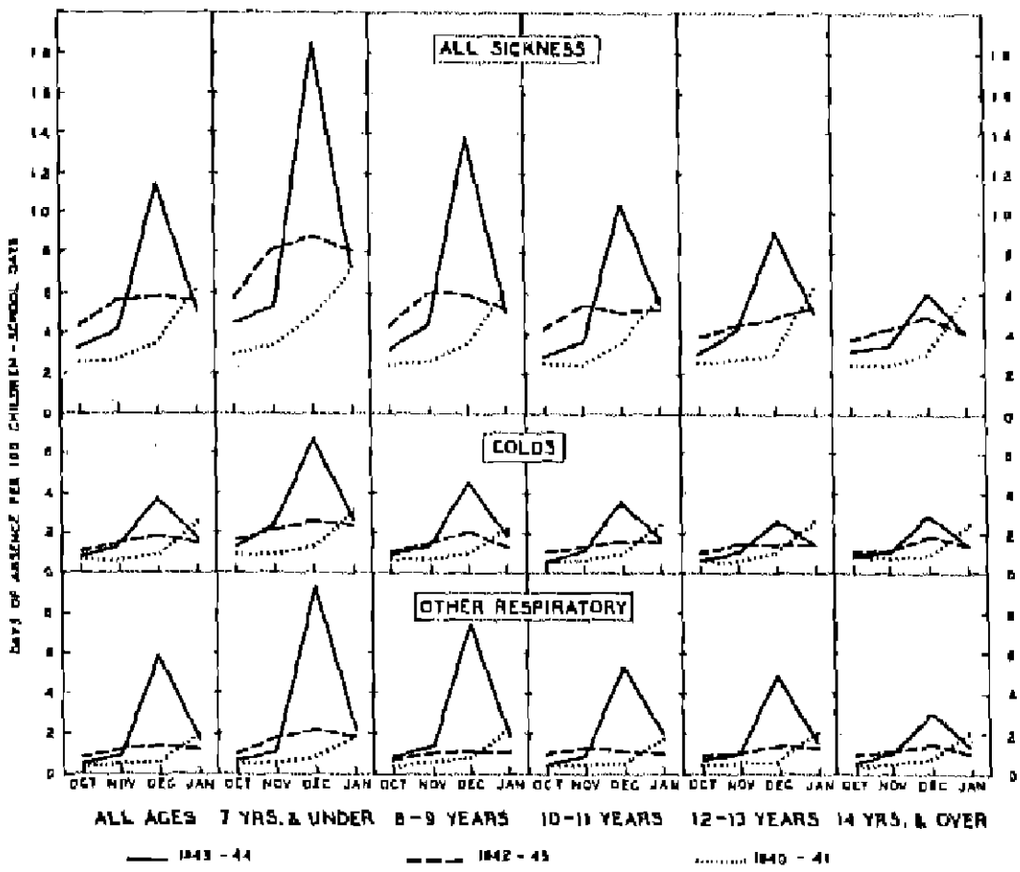

Figure 2. Days of absence due to sickness per 100 children-school days, from all causes and from colds and other respiratory conditions - Hagerstown white school children, October 1943-January 1944.

repeated in 1942-43. Previous studies of absenteeism among Hagerstown school children point to a long-time increase in absenteeism due to minor conditions such as colds and minor digestive disorders (1). This increase may perhaps also be attributed to increase in parental solicitude.

Influenza Outbreak of November-December 1943

Data at hand for the current school year, 1943-44, have not as yet been analyzed. However, because of the interest in last winter's influenza outbreak, data concerning it are presented in this paper. Figure 2 shows the days of absence per 100 children-school days for all sicknesses, for colds, and for other respiratory ailments. Because of the mild form of the disease probably no sharp distinction was made between colds and influenza. Two principal observations are to be made regarding the contents of the chart. The first is the explosive character of the outbreak and its very rapid subsidence, so that by January the rate of absence due to illness returned to "normal." The rate of absence due to sickness in December 1943 was over twice that in December 1942 and over three times that in December 1940.

The second important observation to be made lies in the differences among the age groups. As age increased, the rate of absence for respiratory ailments dropped. It does not necessarily follow that the disease case rate was lower. The age difference in absenteeism could reflect; instead, the greater readiness on the part of the parents of younger children to keep them at home when illness threatens.

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AUTISTIC THINKING AS A "TRANSITORY PHENOMENON OF CHILDHOOD"

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The research for this report resulted from reading a description of T. V. Moore's report on the reasoning ability of young children (3) in Norman L. Munn's chapter on Basic Symbolic Processes of Children (4, chap. 11, p. 367 f). Munn cites Moore's study as presenting the only evidence available, to the date of publication of his book, on autistic thinking in childhood, and presents a thorough coverage of Moore's findings and conclusions. Moore's research (3) was not confined to the investigation of autistic thinking in childhood. In an effort to devise a reasoning test for the insane he presented a triple group of reasoning tests to 205 school children as a preliminary survey with the intention to standardize his test in terms of the intelligence of the child. His test, which he presents in full, was made up of three types of problems: 1) reasoning, 2) autistic fallacies, and 3) logical fallacies. For problems 1 and 3, Moore's findings are in general agreement with those of other research workers on these aspects of mental development in childhood.

A critical evaluation and summary of research on development of reasoning ability in childhood has been presented by Huang (2), who concluded from the assembled evidence that natural phenomena are seldom explained in animistic or magical terms by children and that, while their everyday conceptions of reality and causality "may be simple, naive, and incorrect, they are of the same warp and woof as the 'physical' conceptions of the everyday man in the street." He further states that normal experiences impose fairly valid conceptions of causality upon the growing mind of the child while the type of causality indicated by the child in answering questions is determined by age, intelligence, cultural milieu and, above all, the form and content of the question. The last point made here will be of importance when Moore's results on autistic thinking in childhood are considered. Huang, whose report covers the available literature on the development of reasoning ability in children up to its publication in 1943, further states that "child animism simply means ideas obtained from the biological and social spheres misapplied."

Munn (4, chap. 11), also surveyed the literature up to his date of publication (1938) and except for the statement, "Moore believes that autistic thinking is a transitory phenomenon of

childhood,"[1] concludes that "there is clear evidence that ability to reason improves gradually as a function of age. There is no clear evidence that the reasoning processes of children are qualitatively different from those of adults. Differences between child and adult reasoning may be attributed to differences in the amount of information possessed."

Huang and Munn adequately cover experimentation and results on childhood development in reasoning ability for the purposes of this paper. The principal concern here is with autistic thinking in childhood, a special aspect of the development of reasoning ability in children, which appears to have been studied directly only by, and defined especially only by, Moore in his 1929 publication (3).

Moore's Definition and His Test

Moore defined autistic thinking, which pathologically is most developed in schizophrenia or paranoid states (6), as a "tendency to draw conclusions based on a pathological major in the sense of a false premise that has no basis in logical common sense." A somewhat similar definition of autistic thinking may be added here from Hollingworth (1, p. 234) who states, "autistic thinking is not thinking freed from reality, it is thinking that strays far beyond perception and does not dip back into it again. That is, its meanings are not finally realized in preceptual completeness, or in Dewey's terms, are not verified."

Moore's discovery of autistic thinking as a phenomenon of childhood is incidental to his standardization of a test which aimed to measure the child's ability to detect and reject such thinking. This test comprised the following four statements which were presented to each of 205 school children, 6 to 12 years of age, with a request that they state whether each statement was correct or incorrect followed by a request to tell why the answer just given was believed to be right:

1) If I had a thousand dollars, I could satisfy my heart's

[1] *"Moore's results on verbal reasoning show that adults make better scores than children, but there is no evidence of an essentially different reasoning process in the two groups. In detection of logical fallacies similar results were obtained. There was a rather wide divergence between scores of children and adults in the detection of autistic fallacies. Moore believes that autistic thinking is a transitory phenomenon of childhood since he failed to find it in many adults. However, the difference between children and adults may be largely linguistic in origin." (4, p. 369)*

desire. But I must satisy my desires. Therefore, I have a thousand dollars.

2) If one washes he cleanses himself from dirt. If one sins, he is dirty. If one washes, he cleanses himself from sin.

3) One who does wrong helps toward the destruction of the country. I have done wrong. Therefore, I am responsible for the destruction that is coming on the world.

4) If one is like another in a great many points, he is the same thing as the other. But a man I know has the same duties to take care of the country as the President, he thinks like him, and looks like him. Therefore, this man whom I know is the President.

In scoring this test no account was made of whether the child's answer was correct or incorrect. He was credited with an answer only when he gave a satisfactory response. A satisfactory response to fallacy 1 was any answer which implied that the child understood that desires need not be satisfied in reality no matter how strong they may be to the one who experiences them. For fallacy 2, any answer was considered satifactory which pointed out the distinction between bodily uncleanliness and moral guilt. For fallacy 3, any answer was considered satisfactory which pointed out the disproportion between one individual's wrongdoing and the destruction of the whole world. And, for fallacy 4, any answer was considered satisfactory which implied that the child knew that no matter how much two people resembled each other, they could not constitute one individual.

In applying the above test to his subjects Moore obtained results which indicated that the ability to detect and reject autistic fallacies is just beginning to develop by the 12th year of age. It was found that no 6-year-old children and no 7-year-olds could detect and reject any of the fallacies. The 8-year-old group detected only 1.25 per cent of these fallacies; the 9-year-olds 4.00 per cent; the 11-year-olds 14.2 per cent; and the 12-year-olds only 23.1 per cent. This test was also administered to 113 first year women college students who were able to detect and reject 83 per cent of the total fallacies presented. In addition to the above results, Moore found that while 8- and 9-year-old children begin in a small way to detect and reject autistic fallacies, children of about 10 years of age show a tendency to reason autistically. His evidence for this finding is in

the form of a table (3, Table 4, p. 25) in which it is shown that nine subjects with C.A.s ranging from 9-8 to 11-9 and M.A.s ranging from 9-6 to 12-5 accepted autistic fallacies. This group, slightly superior as to M.A., are shown, through the reporting of their responses to the fallacies, to have supported a relation between bodily uncleanliness and moral guilt, fallacy 2, in eight cases, and a relation between individual wrongdoing and world destruction, fallacy 3, in one case. With this evidence, plus the fact that no one in his group of 113 women college students accepted and supported a fallacy, Moore concludes that autistic thinking is a transitory phenomenon of childhood. Moore states that the inability to detect and reject autistic fallacies "may partially result from the fact that no test to partial out language was used," but he offers no suggestion as to why children of 10 years of age are likely to pass through a period of autistic thinking, as a state of mental growth.

It is believed by the writer that an inspection of the language used in Moore's other two tests of reasoning, logical reasoning and logical fallacies, reveals words or arrangements of words no less complicated or difficult to understand than those found in the test for the ability to detect autistic fallacies. If this is true, it may be that some factor or factors other than "the ability to understand what was said" operated to prevent the subjects from scoring as well on autistic fallacies as they did on logical reasoning and logical fallacies. It is proposed here that part of the reason for failure of Moore's younger subjects to register at all on the autistic fallacies test may have been the fact that the detection of errors in reasoning is foreign to the experience of 6- and 7-year-old children. Furthermore, the autistic fallacies test was preceded by a test of logical reasoning which may have given the subjects a mental set which prevented perception of what was expected of them with the autistic fallacies. That Moore's younger subjects did not do as well on the detection of logical fallacies as they did on logical reasoning is evidenced by the fact (see Table 2) that the 6- and 7-year-olds scored acceptably on 23.1 per cent and 24.8 per cent of the reasoning test items, while they scored only 5.8 per cent and 9.6 per cent, respectively, on the logical fallacies. These scores tend to support the hypothesis that detection of errors in reasoning is more difficult for the young child.

With regard to Moore's discovery of autistic reasoning as a transitory phenomenon of childhood, the writer would argue that this conclusion is based on results obtained through the use of two fallacies which contain pathological majors, in the sense of false premises with no bases in common sense, that are often actually taught to children by adults in a misguided effort

to protect them from moral wrongdoing. An attempt to establish a connection in the mind of the child between sin and dirt is a common practice. A survey of the responses of the writer's subjects who accepted Moore's second fallacy disclosed that they felt it correct for children's mouths to be washed out with soap after the utterance of unacceptable words. The writer has made a casual survey of opinions of middle class mothers with regard to the practice of washing a child's mouth after he says a "dirty" word and found a significant percentage who advocated this as a method of cure. A large number of modern tests in psychology decry current social and moral educational practices with children which set about to establish a connection between sex interests and practices as sin, and dirt or filth. The ceremonies of almost all religious groups in which water symbolically purifies from sin or protects from evil are further common experiences with a connection between washing and relief from sin in the life of the usual child.

With regard to Moore's third fallacy involving a connection between individual wrongdoing and coming world destruction, which furnishes the remainder of the evidence for autistic reasoning in childhood, one has only to listen to some of the religious sermons broadcast by radio to determine that it is entirely possible for the naive child, with no counter teaching in the home, to learn connections of this kind rather than to develop a tendency to originate them as a result of mental growth. In addition to this suggested evidence for the possibility of such connections being learned, the writer submits partial results from an unpublished questionnaire study, done in 1943, which indicate that significant percentages of theological students, Sunday School teachers, and parents would have young children taught that "the present war results from man's failure to please a personal God who has sent the war for punishment." These criticisms of Moore's use of fallacies 2 and 3 and of his interpretation of results obtained appear to be supported in the statement of Huang referred to on page 80 of this paper.

Subjects and Procedure in the Present Experiment

The subjects of the present experiment were 70 public and private school children.[2] These were selected so as to have 10 at each age level for years 6 to 12 and to have 5 in each group

[2] *Sixty of the subjects were pupils at the Hunter Model School, Hunter College, New York City, and 10 were pupils of the Horace Mann School, New York City.*

who were of average or slightly superior I.Q. and five of exceptionally superior I.Q. The subjects of exceptionally superior intelligence were used because the writer entertained an hypothesis that the detection and rejection of autistic fallacies might depend more upon M.A. than upon C. A.

Since the hypothesis was entertained that failure of Moore's subjects might have resulted from inexperience in detecting errors in reasoning plus a mental set to solve problems from the preceding logical reasoning test, it was decided to administer the following items from the 1937 revision of the Stanford Binet Test, form L (5), before administration of Moore's autistic fallacies: 1, Picture Absurdities I, e.g. a) man with umbrella, etc. with all four of the Binet test items of this kind used; 2, Verbal Absurdities, e.g. a) "They found a man locked in his room with his hands tied behind him and his feet bound together. They think he locked himself in," etc. with all four such items used; 3, Finding Reasons, e.g. a) "Give two reasons why children should not be too noisy in school," etc. with all four such items used. Numbers one and two were included because they are items which require the subject to detect errors and because it was hoped that they might promote a mental set in a direction conducive to the detection of autistic fallacies. Item three was included because the subjects are required to support their answers of "correct" or "incorrect" to the presentation of each of Moore's fallacies.

All of the above items were administered in accordance with the manual of instructions for the Stanford Binet Test (5). At no time was the subject informed as to correctness or incorrectness of his responses and no information of any kind was given as to a possible connection or relationship between the type of reasoning required by some of the test items and that required when the fallacies were administered. The Binet items were administered individually in the order given above and were immediately followed by the individual oral presentation of Moore's four autistic fallacies. After the examiner had read a fallacy the subject was asked to state whether it was correct or incorrect and, following this, to tell why he believed his answer was right. As in Moore's study, the subjects' statements as to the correctness and incorrectness of the fallacies were disregarded. They were credited with answers only when satisfactory responses were given. The criteria for satisfactory responses are given in detail on pages 90 and 91. Since the Binet items served only as a test to precede the autistic fallacies test, no report will be made here on scores earned by the subjects. For the reader's information, however, no subject failed all of the Binet items and almost all of the subjects

passed a major percentage of the items.

Results of the Present Study

The results of this study are shown in Tables 1 and 2. Table 1 shows a gradual increase in ability to detect and reject autistic fallacies with increase in chronological age from the sixth to the twelfth year. Since subjects of exceptionally superior I.Q. made better scores on the test at all age levels than do subjects of only slightly superior I.Q., a claim may be made for a relationship between mental age and ability to detect autistic fallacies that may be greater than the relationship between the ability and chronological age.

A comparison of Tables 1 and 2 shows that the subjects of the present report differ radically from Moore's subjects in growth of the ability to detect and reject autistic fallacies. The data of the present study, Table 1, offer evidence that the growth of this ability does not differ significantly from the growth of ability to solve logical reasoning problems and to detect logical fallacies. The fact that the subjects of the present report made better scores on the autistic fallacies test than Moore's subjects made on his logical fallacies test may be due to selection, since even the "slightly superior I.Q. group" of this study appears to be more selected as to intellectual status than the average of Moore's subjects, whose I.Q. range was between 90 and 110. The fact that the subjects of this study who were of exceptionally high I.Q. made better scores on the autistic fallacies test than did Moore's adult subjects, Table 2, appears to further support the claim for a closer relationship between M.A. and ability to detect and reject autistic fallacies than between C.A. and this ability.

With regard to Moore's finding of a tendency for children to reason autistically as a "transitory phenomenon of childhood," the following results were obtained. At the 6-year level four of the "exceptionally superior I.Q. group" accepted and supported five fallacies, or 25 per cent of all fallacies presented to the group. In three of these instances, the fallacy accepted was Number 2 which involves a connection between sin and dirt. In the remaining two instances, the fallacy accepted was that which involves a connection between individual wrongdoing and coming destruction of the world. It is interesting to note, Table 1, that the mean I.Q. of this 6-year-old group is 167, which means that their mean M.A. approximates that of Moore's 10-year-old group which furnished evidence for his conclusion that autistic reasoning is a transitory phenomenon of childhood. To continue with the results of this study: at the

TABLE 1

THE DEVELOPMENT OF ABILITY TO DETECT AND REJECT AUTISTIC FALLACIES AS A FUNCTION OF CHRONOLOGICAL AGE AND I.Q.

	Slightly Superior I.Q. Group Five Subjects at Each Age Level						
C.A. Years	6	7	8	9	10	11	12
I.Q. Range	107-114	103-110	97-106	103-118	105-121	108-114	108-122
I.Q. Mean	114	111	103	109	112	110	112
Per cent of autistic fallacies detected	20	25	60	55	65	85	90
	Exceptionally Superior I.Q. Group Five Subjects at Each Age Level						
C.A. Years	6	7	8	9	10	11	12
I.Q. Range	165-172	161-167	161-184	168-174	153-169	161-178	139-150
I.Q. Mean	167	164	172	170	158	169	143
Per cent of autistic fallacies detected	25	50	90	90	95	100	100

7-year level, three of the slightly superior I.Q. group accepted three, or 15 per cent, of the total fallacies presented. In one instance, the fallacy accepted was Number 2 and in the remaining instances, it was Number 3. At the 8-year level two, or 10 per cent, of the fallacies were accepted by two members of the "slightly superior I.Q. group" and one, or 5 per cent, was accepted by an "exceptionally superior I.Q." subject. In all three instances, the fallacy accepted was Number 3. At the 9-year level two, or 10 per cent, of all fallacies presented to the group were accepted by one slightly superior I.Q. subject. This subject accepted and supported fallacies Numbers 2 and 3. No other

TABLE 2

A SUMMARY OF MOORE'S RESULTS SHOWING THE DEVELOPMENT OF LOGICAL ABILITY AS A FUNCTION OF CHRONOLOGICAL AGE

205 Subjects with I.Q. Range from 90 to 110

C.A. Years	6	7	8	9	10	11	12	113 1st year college women
Per cent of reasoning items passed	23.1	24.8	32.1	43.1	51.1	56.0	63.2	88.0
Per cent of autistic fallacies detected	00.0	00.0	1.25	4.0	3.05	14.2	23.1	83.0
Per cent of logical fallacies detected	5.8	9.6	21.9	27.3	36.0	53.7	54.8	80.0

fallacies were accepted by the subjects of this report. These results appear to support the contention that autistic thinking in childhood is more a function of the content of the material presented to the thinker than of the growth of reasoning ability. It may be of interest that a significant proportion of the responses of subjects who accepted fallacy Number 3, which involves a connection between individual wrongdoing and coming world destruction, were attempts to use the fallacy as presented to explain the causes of the present war, which apparently was considered to be "the destruction that is coming on the world."

Summary and Conclusions

Seventy children ranging in C.A. from 6 to 12 years, with ten at each age level, have been given an autistic fallacies test devised by T. V. Moore. The procedure of administration of the test differed from Moore's in that it was preceded by certain selected items from Form L of the 1937 Revision of the

Stanford Binet. The subjects differed somewhat from Moore's subjects in that half of each age level group was slightly superior in intellectual status to his subjects and the remaining half were definitely superior.

The results obtained support the following conclusions:

1. There is no essential difference between the development of the ability to detect and reject autistic fallacies and the development of the ability to reason logically or to detect logical fallacies.

2. There is a close relationship between the ability to detect autistic fallacies and mental age since children of exceptionally high I.Q. made better scores on the test than did 113 first year college women tested by Moore.

3. There is no evidence to support a conclusion that "autistic reasoning is a transitory phenomenon of childhood."

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STUDIES OF THE CENTER OF GRAVITY IN THE HUMAN BODY

CARROLL E. PALMER[1]

Introduction

The position of the center of gravity in the human body has been studied from various points of view by anatomists and physiologists for many years. The earlier investigators were primarily concerned with the theoretical significance of locating the center of mass of the body. Later workers have emphasized the importance of considering the effects of gravity in problems of the mechanics of posture and locomotion. More recently the center of gravity of the human fetus has been studied in connection with certain obstetrical problems. At various times the situation of the center of gravity has been considered an important factor in the estimation of various types of body build and body form. Although extensive studies have been made on the position of the center of mass of the human body, no adequate method has been described for the finding of this point and most of the studies have been based upon analysis of very few observations.

It was the aim of this research to develop an accurate and expedient method for the determination of the center of gravity in the living body and to apply this method to a sufficiently large series of cases to permit a statistical analysis of some of the more important influences which the force of gravity may have on the human body. It is believed that a study of this kind may throw some light upon various problems of the growth of the body and in particular to be of importance in connection with certain problems of the mechanics of child physiology as applied to motor activity and motor coordination. It is the purpose of the present paper to show detailed determinations of the

[1]*Work upon this paper was begun during the writer's tenure as a Teaching Fellow, Department of Anatomy, University of Minnesota, and completed during his tenure (1928-1930) as a National Fellow for Research in Child Development, Committee on Child Development, National Research Council.*

At the time of doing the study, the writer expressed his appreciation of Professor R. E. Scammon's guidance in every phase of this study, and of Professor J. E. Anderson's generous support; and his gratitude to Mr. E. N. Rosell, then Superintendent at Mooseheart, Illinois, for the opportunity to work at Mooseheart; and to the late Dr. J. D. Nichols, then resident physician at Mooseheart, and his staff, for the cooperation which was so graciously given.

center of gravity for a relatively large series of cases, with only brief references to certain historical aspects of the problem and a short description of the apparatus devised by the writer.[2]

Since the series of cases, with which this paper is concerned, included both sexes and all ages from birth to adulthood, it is believed to present for the first time comprehensive observations on the principal changes in the location of the center of gravity for the entire developmental period of postnatal life. A limited number of observations on fetal cadavers are also included; but the major emphasis is on living subjects.

The history of experimental attempts to determine a plane of gravity or the center of gravity of the human body goes back to the 17th century when Borelli (1680) reported his balance-board experiments and thus was the first investigator to report on even an approximation of the location of the transverse plane of gravity. The Webers, over 160 years later (1836), did the first quantitative work on the problem and were able to report for two subjects both the absolute height of the transverse plane above the soles, and its relative height, expressed as a percentage of body length or stature. The numerous subsequent workers who have attacked the problem have very generally done one of two things: 1) many have used only cadavers (adult) or fetuses placed in the intrauterine position, and 2) others have reported their findings in such a way that few are mutually comparable and even fewer give sufficient information to permit an exact anatomic location of the center. Furthermore, there has been little study of the course of change in the position of the center over the developmental periods of postnatal life. It has long been known that the center of gravity in the newborn is close to the posterior margin of the diaphragm, while in the adult it is in the second or third sacral vertebra. However, the course of its change in location and what factors affect that change have remained uninvestigated and few, if any, detailed observations have heretofore been available.

In general, methods and apparatuses have been devised to locate a single plane through the body which contains the center of gravity; in certain instances this has been a transverse section of the body (Borelli, E. Weber and W. Weber, Duncan; du Bois-Reymond; Barnum; Griffith; Scheidt; and Croskey, Dawson, Luessen, Marohn and Wright); in other instances this has been a frontal plane of the body (Meyer; Richer; Haycraft

[2] *For more complete details as to apparatus and for a review of the literature the reader is referred to: "Center of Gravity of the Human Body during Growth," by Carroll E. Palmer (Am. J. Phys. Anthropol., 1928, XI, 423-455).*

and Sheen; Reynolds and Lovett, Hesser; and Resmark). Nearly all the investigators have assumed that the midsagittal plane of the body passes through the center. However, two methods (Harless, and Braune and Fischer) have been devised for locating the point of gravity in the dead body. One method (Solls) has been developed for finding the position of the true center in the living body.

A study of all of these methods leads the present writer to the conclusion that none of them has proved satisfactory. Only the later workers in this field (Scheidt; and Croskey, Dawson, Luessen, Marohn and Wright) were sufficiently confident to make a study of more than a few cases, and Scheidt himself expressed the opinion that present methods were not adequate to handle the problem successfully. The researches of Solls are, however, exceptional. Without doubt his measurements are accurate and his results precise. Nevertheless, it must be admitted that his experiments were made with great care upon cooperative subjects and that such results could be obtained only under very favorable conditions.

A review of the aggregate results of the various investigators indicates the present status of this problem. As reported in the available literature, determinations of the position of the transverse plane of gravity have been made in a total of 760 subjects. Of this number the actual measurements have been published for 84 subjects of which 54 were fetal bodies placed in the intrauterine position. Of the remaining 30 cases, only 23 were living subjects. The data covering the position of the center of gravity in other planes include a total of 82 determinations. Again, 54 of these observations were made upon fetal specimens and an additional 7 were made upon dead bodies. If the prenatal period is excepted, it is apparent that, although a comparatively large number of determinations have been made, very few are available for further study and analysis. It is especially regrettable that the extensive studies of Scheidt, and of Croskey, Dawson, Luessen, Marohn and Wright were published in such abbreviated form as to be practically useless for further study.

It appears to the writer that Griffith's study of the influence of gravity upon the fetal body has quite adequately solved most problems concerned with that period of development. Both the relative and actual positions of the center of gravity of the fetal body while in the intrauterine posture have been clearly demonstrated.

The location of the center of gravity in the mature and adolescent body has been fairly well established by the careful work of E. and W. Weber, Harless, Braune and Fisher, and

Solls. However, essentially nothing is known of the factors concerned with the very marked change in its location over the developmental ages nor of the influences which the force of gravity may have upon mechanical problems during infancy and childhood.

Methodology

Introductory Note

A review of previous methods and apparatuses used to determine the center of gravity of the human body has enabled the writer to establish certain criteria that he believes should be fulfilled if an adequate investigation is to be made of this problem. The fundamental points laid down in these criteria are as follows:

The first point requires that the center of gravity be located in two-dimensional space. Careful consideration of this part of the problem has led to the conclusion that it is not feasible to attempt to locate the center of gravity in a sagittal plane. The human body is, of course, not perfectly symmetrical. In order to determine a sagittal plane through the center of gravity the subject must assume a symmetrical posture. Two factors are therefore involved, the actual (and usual) asymmetry of the body, and the errors introduced by asymmetry of posture. The difficulty of experimentally separating these two factors is so great that for the present no provision can be made for determining this plane. However, the two remaining planes, the transverse and frontal, which pass through the center should be located. In addition, it is important that both planes be determined while the subject is in the same position. If possible, both planes should be located simultaneously; at least, the subject should assume the same posture during the determination of each plane.

The second point to be considered concerns the methods of expressing the position of the center. If comparisons are to be made, and if any considerable number of cases is to be studied, it is essential that the center be located with respect to certain well-defined anatomical landmarks. It will be important, also, to localize the center in a purely anatomical situation, but the great individual variability of organs and structures makes it of even greater significance to determine its position relative to the body as a whole.

The third criterion deals with the subjects to which the method may be applied. From several points of view it is desirable to study living subjects since if facts are to be determined concerning the influences of gravity upon the living, it is necessary to study living individuals. The effect of gravity upon the body is continuously present and if a comprehensive study is to be made, the method must be equally applicable to subjects of any age.

The fourth consideration involves the accuracy and general applicability of the method. Of prime importance is the accuracy which may be obtained. From a practical viewpoint, however, measurement of the center of gravity should be as precise as other bodily measurements. The general applicability of the method and apparatus is of great importance. If children are to be studied it is essential that determinations be made quickly and easily without a great deal of cooperation from, or manipulation of, the subject. The method described in this paper was finally evolved after consideration of all these points.

Apparatus

The apparatus designed in the present study utilizes the principle of moments of force about a fixed point. In general it is based upon the fundamental principles of the methods of du Bois Reymond, Scheidt, Reynolds and Lovett, and of Hesser, and combines the essential features of the apparatuses of all these investigators.

The apparatus itself consists of a rectangular steel frame, to the undersurface of which are attached two wedges or knife edges; one wedge acts as the fulcrum, the other as the force point. At one end of the steel frame is hinged a flat platform upon which the subject lies in the supine position. This platform is so constructed that it may be fixed firmly in three positions, either horizontal and parallel with the supporting frame or tilted in such a manner that the subject lying upon its surface is inclining at a known angle to the horizontal. When the subject lies in the horizontal position upon the platform, his transverse plane of gravity may be determined by the simple procedure of du Bois-Reymond or of Scheidt. When the platform is elevated into the inclined position, the location of the frontal plane of gravity may be calculated by a method analogous to that of Reynolds and Lovett or of Hesser. The determination of the position of the center of gravity in these two axes is shown diagrammatically in Figure 1, which is a schematic out-

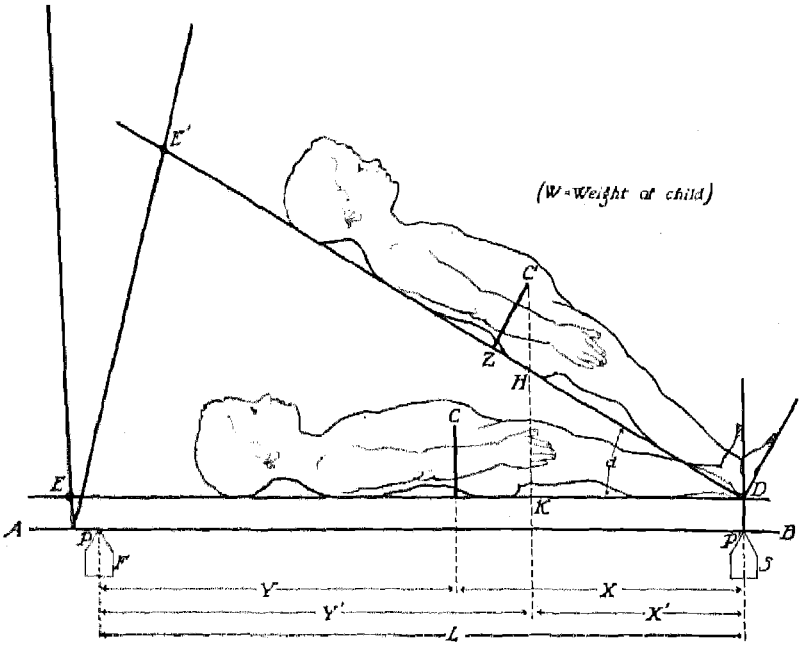

Figure 1. Method employed to determine the transverse and frontal planes through the center of gravity of the human body.

line drawing of the apparatus showing a subject in position. The line AB represents the cross-section of the rectangular steel frame to which is hinged the platform indicated by the line DE. The subject lies in the supine position upon the platform DE with his feet firmly against the upright footboard placed at D. The point of rotation of this platform is exactly at the point D. The wedge shown at the point P rests upon a fixed stationary support, while the wedge shown at the point P' rests upon the pan of a scale. The center of gravity of the subject is represented as C and C'. For the purpose of this description, it is assumed that the weight of the apparatus is negligible and that the weight supported by the wedges is due only to the weight of the body, W. The portion of this weight supported by the fixed wedge is represented as F, and that supported by the scale as S. The relative magnitudes of F and S, then, depend upon the position of the vertical plane of gravity; that is, the plane which passes vertically downward through the point C. The

nearer this plane approaches either wedge, the greater must be the weight which that wedge supports. The distance between the two wedges is indicated as L, and the distances from the vertical plane of gravity to either wedge are correspondingly indicated as X and Y. The distance X, therefore, marks the distance of the transverse plane of gravity above the soles of the feet. The proportional relationships between these factors may be expressed in various ways:

$$F : S :: X : Y \text{ or } W : S :: L : Y$$

From the second expression it may be seen that

$$SL = WY, \text{ and } Y = \frac{SL}{W},$$

And because $X + Y = L$,

$$S = L - \frac{SL}{W}$$

Then, in this last equation: S equals the force upon the scale and can be experimentally determined; L is the distance between the wedges and is a constant factor; W is the weight of the body and can be directly determined. With these factors known, X, or the distance of the center of gravity above the soles of the feet, can be calculated.

The platform is now rotated through the angle α into the position shown as E'D. In this position the plane of gravity will fall vertically from the point C' and cut the horizontal at the point K. Under these conditions, X' represents the distance from the plane of gravity to the point P', while Y' represents the corresponding distance to the point P. In this position a new value of S will be obtained and the value of X' can be calculated by means of the same formula used to determine X. After the values of X and X' have been found, the distance C'Z or the distance of the center of gravity above the surface of the platform upon which the subject is lying, can be calculated as follows:

In the triangle DHK:

α = the angle through which the platform is rotated.

$$\cos \alpha = \frac{KD \text{ (or } X')}{HD} \text{ and,}$$

$$HD = \frac{X'}{\cos}$$

In the triangle ZHC':

$$ZH = ZD \text{ (or } X) - HD \text{ (or } \frac{X'}{\cos \alpha})$$

$$ZH = X - \frac{X'}{\cos \alpha}$$

$$\text{But } \tan \alpha = \frac{ZH}{ZC'} \text{ or}$$

$$ZC' = \frac{ZH}{\tan \alpha} \text{ therefore,}$$

$$ZC' = \frac{X - \frac{X'}{\cos \alpha}}{\tan \alpha}$$

X and X' were determined in the initial calculations and the trigonometric functions of the angle α are known constants. Therefore, the distance of the center of gravity above the upper surface of the platform, or the position of the frontal plane of gravity, can be determined.

The technical details of the apparatus, as used for determining the center of gravity in infants and small children, have been described in full detail elsewhere (in the paper previously cited). The apparatus, as changed to be suitable for use with adults, is shown in Figure 2. The basic principles are the same as those embodied in the original apparatus.

Technique of Determination

A detailed description of the actual procedure for making a determination of the center of gravity is given here to demonstrate the facility with which this method and apparatus may be applied to the study of living subjects.

The subject is first placed in the supine position upon the platform of the gravity device in the manner shown diagrammatically in Figure 1. The heels are placed together, firmly against the footboard. The legs are together and completely extended. The trunk lies flat upon the platform. The arms are placed along the trunk with the palms flat upon the thighs. The head is held straight with the face horizontal.

A counterweight (see Figure 2) is turned to its proper position to balance the apparatus, the screw carrying the scale point is adjusted to level the apparatus and compensate for the depression of the scale. As soon as these adjustments have been made, the weight upon the scale is read.

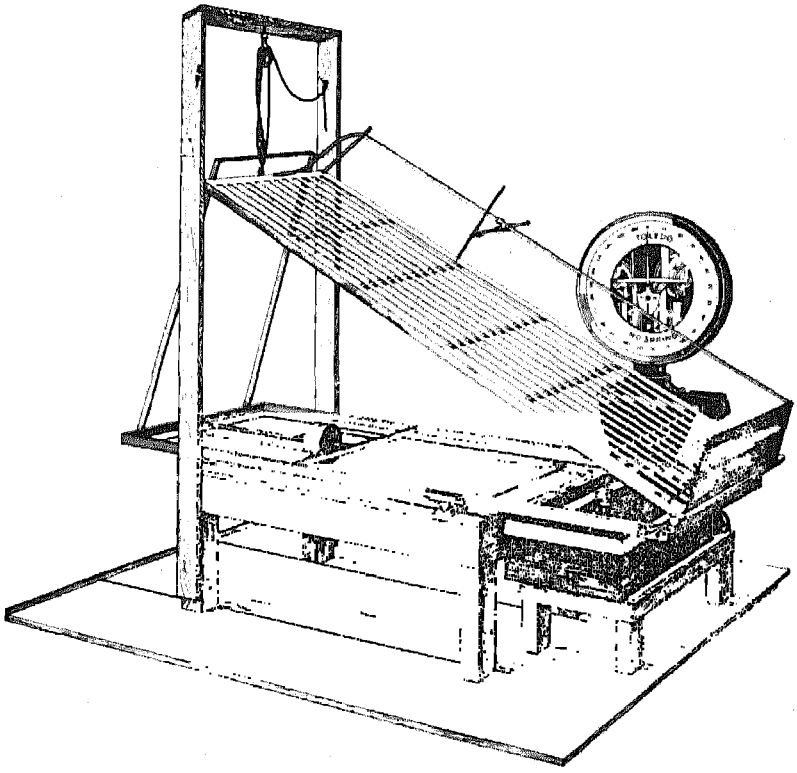

Figure 2. Revised apparatus for determining the transverse and frontal planes through the center of gravity.

The flat platform is then moved to the first inclined position. The counterweight is turned to its proper setting for this angle of elevation, the screw scale point is adjusted to level the apparatus, and the scale reading is again recorded.

The platform is moved to the second inclined position and, after again adjusting the level and counterweight, the third reading is recorded.

It is important that the subject does not alter his position during the few minutes required to obtain these three readings.

The subject is then removed from the apparatus; the table carrying the gravity device is rolled away from the scale; and the natural body weight of the subject is determined by means of the same scale.

Thus four scale readings have now been obtained: body

weight, the weight on the apparatus in the horizontal position, and the two weights in the inclined positions. These four values are the only variables necessary for the calculation of both the transverse and frontal planes of gravity. The details of the actual computation are not significant except to show that they may be simplified to a considerable extent by the use of algebraic and trigonometric combinations. The final formulae in which substitutions are made are given in order to demonstrate the actual simplicity of the calculations.

Distance of transverse plane from soles $= 74.8 \left(1.599 - \frac{S0^{0}}{W}\right)$,

Distance of frontal plane from back $(25^{0}) = 185.0 \frac{S25^{0}}{W} - 169.2 \frac{30^{0}}{W} - 25.26$ cm.,

Distance of frontal plane from back $(30^{0}) = 143.8 \frac{S30^{0}}{W} - 122.8 \frac{S0^{0}}{W} - 33.54$ cm.

Where $S0^{0}$ = the scale reading in the horizontal position,
and $S25^{0}$ = the scale reading in the 25^{0} position,
and $S30^{0}$ = the scale reading in the 30^{0} position,
and W = the weight of the body.

Figure 3 shows the photographs of several children in whom the center of gravity has been determined. The photographs on the upper and those on the lower line show the position of the transverse plane of gravity marked upon the body by means of a skin pencil. In the central photograph the position of the frontal plane is shown by a vertical line.

Precision of Apparatus

The accuracy of determinations of the center of gravity has been carefully investigated. Theoretically, the precision of the apparatus is dependent upon these factors: 1) the precision of the scale used with the apparatus, and 2) the accuracy with which the subject may be placed in position upon the platform. The variability of the center of gravity due to inaccuracies of the scale was worked out, in part, before the apparatus was constructed.

At first a small scale was used for determining the center of gravity in infants and young children. It was graduated in 10 gm. intervals and it was assumed, after some investigation, that weighings could be made within an accuracy of 25 gm. The effect of this degree of precision was then calculated and the

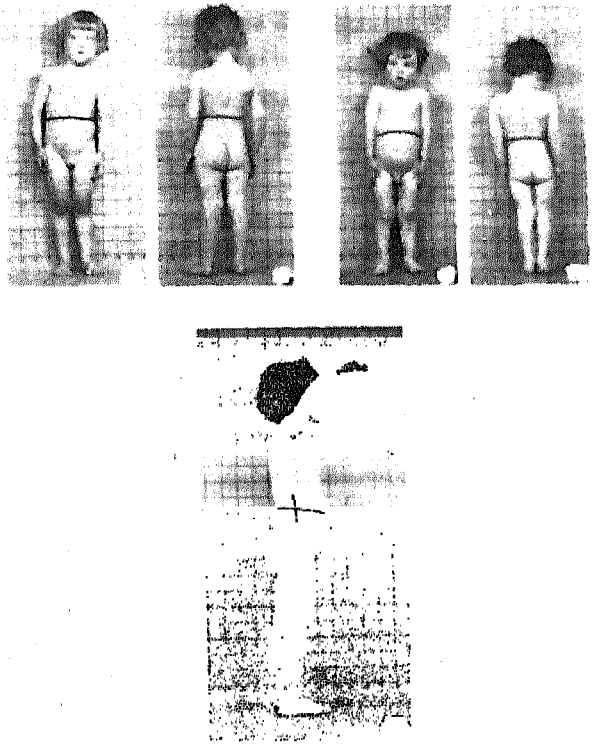

Figure 3. Photographs of 4 children showing the position of the planes of gravity. The central figure shows the position of both the transverse and frontal planes marked upon the lateral aspect of the body.

Table 1

Theoretical estimates of experimental error due to use of small scale

Age	Stature*	Weight	Plane of gravity: From soles	From 30°	back 45°	Maximum theoretical change of center of gravity produced by variation of 25 gm.: From soles	From 30°	back 45°
	(cm.)	(kg.)	(cm.)	(cm.)	(cm.)	(cm.)	(cm.)	(cm.)
1 mo.	52.8	3.940	31.27	8.41	-	0.54	2.08	-
1 yr.	75.8	10.950	44.20	7.22	6.98	0.16	0.64	0.46
4 yr.	104.0	18.025	59.19	6.69	6.56	0.07	0.29	0.16

*Crown heel measurement

Table 2

Theoretical estimates of experimental error due to use of large scale

Age	Stature	Weight	Plane of gravity: From soles	From 30°	back 45°	Maximum theoretical change of center of gravity produced by variation of 1/8 lb.: From soles	From 30°	back 45°
(yr.)	(cm.)	(lb.)	(cm.)	(cm.)	(cm.)	(cm.)	(cm.)	(cm.)
3	101.2	33 1/8	58.13	6.02	6.09	1.23	1.70	1.06
7	115.1	54 3/4	63.92	7.00	6.89	0.52	0.94	0.66
13	160.0	87 7/8	90.14	7.91	8.03	0.20	0.60	0.40
24	179.7	165 1/2	100.45	9.82	9.96	0.09	0.31	0.22

results of three theoretical examples are shown in Table 1. It was found, for instance, that a deviation of 25 gm. upon a 4 kg. subject resulted in a change of about 0.5 cm. in the position of the transverse plane of gravity. This amount of variation in the scale caused a much greater deviation, about 2.0 cm., in the theoretical frontal plane of gravity. In larger subjects the effect of this deviation becomes progressively less so that, in a child weighing 20 kg., the variation in the transverse plane is only 0.07 cm. and in the frontal plane it is less than 0.3 cm. A larger scale used with older subjects was assumed to be accu-

rate within 1/8 lb. (under 60 gm.). The results for three theoretical cases are shown in Table 2. In a child weighing 88 lbs. the effect of a variation of 1/8 lb. was found to be approximately 0.2 cm., when translated into terms of the distance of the transverse plane of gravity from the soles; and to be approximately 0.6 cm. in terms of the distance of the frontal plane from the back.

Thus it was shown that it is theoretically possible to determine the position of the transverse and frontal planes of gravity with a high degree of precision. When it is considered that the most reliable linear measurement of the body, standing height, can be made with a precision of only 0.5 cm. (Boyd '29, Todd '25, Todd and Lindala '28), the possibilities of this apparatus appear to be well worthy of investigation.

The second factor, the variability due to inconstancies of the position of the subject upon the apparatus, could not be ascertained theoretically. It was desirable to test this point as well as to check, experimentally, the deviations produced by inaccuracies of the scale. In order to accomplish this, and also to find any other possible source of error, the following experiment was carried out.

Two large wooden blocks were obtained, and a series of observations upon them was statistically analyzed. These experimental objects were solid blocks of pine. Block 1 measured 508 mm. in length, 170 mm. in breadth, and 189 mm. in height. Block 2 measured 620 mm. in length, 96 mm. in breadth, and 96 mm. in height.

The centers of gravity of these two blocks were determined by means of the balancing method of Borelli and also by means of the suspension method of Braune and Fischer. Several observations were made by both of these methods and it was possible to make a close approximation to the position of the center of gravity. The center of Block 1, by these methods, was found to be 254 mm. from a marked edge, for the transverse plane, and 94 mm. from the marked edge for the frontal plane. The center of Block 2 was 312 mm. from a marked edge for the transverse plane and 48 mm. from that edge for the frontal plane.

A series of measurements was next made upon each block using the apparatus designed for this study. The results of these observations are shown with the means, their probable errors, ranges, mean deviations, standard deviations, and coefficients of variability with their probable errors, in Table 3. This table shows that the transverse plane of gravity in Block 1 is 254.3 mm. from the marked edge, 94.0 mm. from this edge in the frontal plane as determined in the first inclined position, and 94.2 mm.

Table 3

Summary of experimental findings on the variability of the inert test objects

	Block No. and item	Mean	Range	Mean deviation	Standard deviation	Coefficient of variability (percent)
1	Weight	9867.3 ± 0.77 gm.	25 gm.	5.18 gm.	6.29 gm.	0.064 ± 0.0055
2	Weight	4054.8 ± 0.80 gm.	20 gm.	5.55 gm.	6.52 gm.	0.161 ± 0.0140
1	Scale reading, horizontal	15317.3 ± 1.83 gm.	70 gm.	12.00 gm.	14.87 gm.	0.097 ± 0.0084
2	Scale reading, horizontal	5613.2 ± 1.44 gm.	35 gm.	10.50 gm.	11.72 gm.	0.209 ± 0.0182
1	Scale reading at 30°	17614.1 ± 1.69 gm.	60 gm.	11.66 gm.	13.72 gm.	0.079 ± 0.0068
1	Scale reading at 45°	19330.8 ± 2.15 gm.	65 gm.	15.50 gm.	17.47 gm.	0.090 ± 0.0078
2	Scale reading at 30°	6378.7 ± 1.59 gm.	40 gm.	11.27 gm.	12.90 gm.	0.202 ± 0.0176
2	Scale reading at 45°	7081.5 ± 1.67 gm.	40 gm.	11.86 gm.	13.60 gm.	0.192 ± 0.0167
1	Center of gravity from end	254.3 ± 0.05 mm.	1.6 mm.	0.349 mm.	0.420 mm.	0.165 ± 0.0144
2	Center of gravity from end	313.0 ± 0.06 mm.	2.0 mm.	0.396 mm.	0.507 mm.	0.162 ± 0.0141
1	Center of gravity from side at 30°	94.0 ± 0.06 mm.	1.9 mm.	0.341 mm.	0.452 mm.	0.481 ± 0.0418
1	Center of gravity from side at 45°	94.2 ± 0.06 mm.	1.7 mm.	0.254 mm.	0.458 mm.	0.485 ± 0.0422
2	Center of gravity from side at 30°	47.5 ± 0.09 mm.	3.2 mm.	0.580 mm.	0.734 mm.	1.545 ± 0.1372
2	Center of gravity from side at 45°	47.3 ± 0.08 mm.	2.9 mm.	0.487 mm.	0.611 mm.	1.291 ± 0.1137

from the edge as determined in the second inclined position. In Block 2 the transverse plane is 313.0 mm. from the marked edge, 47.5 mm. from the edge in the frontal plane as determined by the first inclined position, and 47.3 mm. from the edge as determined by the second inclined position.

Further examination of this table shows the precision that may be expected in determinations of the center of gravity of inert bodies by means of this apparatus. It is shown that the simple weights of the blocks vary, on the average, approximately 5 gm., with a standard deviation of only slightly more than 6 gm. These figures, and subsequent observations with this scale, indicate that the actual error is well within the assumed 25 gm. range. The weights recorded when the apparatus itself is incorporated in the determination show a greater variability, but in no case does the standard deviation exceed 20 gm. The distribution of these deviations gives no clue to the actual causes of the variations, but it does demonstrate that the errors are noncumulative.

It will be seen that when these fluctuations in weight are read into the actual linear deviations of the centers of gravity, the largest standard deviation (frontal distance of the center of gravity, Block 2) is .734 mm. Or, expressed in another fashion, the center of gravity in inert objects may be localized within a circle having a radius of three-fourths of one millimeter. It is not assumed that measurements made upon living human beings, especially upon children, can be made with as great precision as upon these inert objects. However, it seems justifiable to conclude that the figures given above represent the errors occasioned by purely mechanical and manipulatory factors and that the reliability of this method and apparatus has been fairly well established by actual experimental measurements. Determinations may be made upon living subjects with the assurance that when the measurements show greater variations, the increase is due to the greater variability of biological material.

The final test of the reliability of this method and apparatus was made by means of seriatim measurements upon three living subjects. These subjects were young boys - Test Case 1 was 8 years and 10 months old, weighed 29.15 kg. and was 131.1 cm. in height; Test Case 2 was 12 years and 10 months old, weighed 37.4 kg. and was 149.8 cm. in height; Test Case 3 was 14 years and 9 months old, weighed 46.95 kg. and was 158.3 cm. in height. Ten successive observations were made upon each subject. Each series of observations consisted of measurements of body weight, standing height, sitting height, the distance of the transverse plane of gravity from the soles, and the distance of the frontal plane from the back as determined in the

Table 4

Seriatim observations and measures of variability on position of center-of gravity and certain body measurements

Test Case 1

Number	Stature	Sitting height	Weight	Plane of gravity			
				From soles	From back 25°	30°	Percentage height from soles
	(cm.)	(cm.)	(kg.)	(cm.)	(cm.)	(cm.)	
1	131.8	72.4	29.14	76.1	7.6	8.4	57.0
2	131.1	73.7	29.14	75.2	8.2	7.7	57.4
3	131.4	73.0	29.20	75.2	7.1	7.4	57.2
4	131.1	71.1	29.14	74.5	7.3	7.1	56.8
5	130.8	70.8	29.14	74.8	7.2	7.3	57.2
6	131.1	70.8	29.20	74.7	6.7	7.2	57.0
7	130.5	72.4	29.14	75.1	7.9	8.1	57.5
8	130.8	71.4	29.14	75.1	7.9	8.1	57.4
9	130.8	70.9	29.14	75.2	7.5	8.3	57.5
10	131.4	72.4	29.14	74.9	7.5	7.5	57.0
Range	1.3	2.9	0.06	0.7	1.5	1.3	0.7
Mean	131.08	71.89	29.15	74.98	7.49	7.71	57.2
Average deviation	0.27	0.85	0.02	0.20	0.33	0.40	0.22
Standard deviation	0.38	0.88	0.03	0.24	0.43	0.47	0.24

two inclined positions, 25° and 30°. The results of this experiment are recorded in Tables 4, 5, and 6. The biometric constants which were considered significant were calculated and are recorded in the tables. A review of this material, and especially of the statistical constants, indicates the reliability with which the method can be applied to the living. Attention is directed, in particular, to a comparison of the standard deviations of standing height and of the height of the transverse plane of

Table 5

Seriatim observations and measures of variability on position of center of gravity and certain body measurements

Test Case 2

Number	Stature	Sitting height	Weight	Plane of gravity			
				From soles	From 25° back 30°		Percentage height from soles
	(cm.)	(cm.)	(kg.)	(cm.)	(cm.)	(cm.)	
1	150.2	76.2	37.41	86.0	8.8	8.9	57.3
2	150.2	75.6	37.35	85.6	8.3	8.6	57.0
3	149.9	76.5	37.46	85.6	6.6	7.2	57.1
4	150.2	75.9	37.46	86.3	8.7	8.8	57.5
5	150.5	76.5	37.35	85.6	8.0	8.6	56.9
6	148.6	75.9	37.41	86.0	8.8	9.5	57.9
7	150.2	75.9	37.35	85.7	8.3	8.5	57.1
8	149.9	76.5	37.41	86.0	9.1	9.0	57.4
9	150.2	75.2	37.46	85.8	8.2	8.2	57.1
10	149.2	76.2	37.35	85.8	9.1	8.9	57.5
Range	1.9	1.30	0.11	0.7	2.5	2.3	1.0
Mean	149.91	76.04	37.40	85.84	8.39	8.62	57.28
Average deviation	0.37	0.30	0.04	0.20	0.51	0.32	0.24
Standard deviation	0.57	0.38	0.05	0.23	0.74	0.38	0.31

gravity. These measurements are themselves directly comparable and, as is shown in the tables, their standard deviations are of the same order of absolute magnitude.

Measurements of the frontal plane of gravity show slightly more variability. The standard deviations are greater, absolutely, than those of either standing height or the height of the center of gravity. They are, however, considerably smaller than the standard deviations of measurements of sitting height.

Table 6

Seriatim observations and measures of variability on position of center of gravity and certain body measurements

Test Case 3

Number	Stature	Sitting height	Weight	Plane of gravity			
				From soles	From back 25°	From back 30°	Percentage height from soles
	(cm.)	(cm.)	(kg.)	(cm.)	(cm.)	(cm.)	
1	158.7	83.8	45.98	89.9	9.5	9.7	56.6
2	158.1	85.7	46.04	89.6	8.8	9.0	56.7
3	158.4	86.4	45.93	90.1	10.0	9.8	56.9
4	158.1	84.5	45.93	89.1	8.8	9.1	56.4
5	157.8	84.5	45.98	89.5	8.9	9.1	56.7
6	158.4	83.8	45.98	89.7	9.1	9.4	56.6
7	158.1	84.5	45.93	89.4	8.7	8.6	56.5
8	158.4	84.8	45.93	89.3	8.6	8.9	56.4
9	158.1	84.5	45.93	89.6	9.1	8.8	56.7
10	158.4	85.7	45.93	89.6	8.6	9.1	56.6
Range	0.9	2.6	0.09	1.0	1.4	1.2	0.5
Mean	158.25	84.82	45.95	89.58	9.01	9.15	56.61
Average deviation	0.27	0.66	0.03	0.20	0.33	0.27	0.11
Standard deviation	0.31	0.86	0.04	0.29	0.44	0.38	0.15

Summary

The manner in which this apparatus satisfies the criteria set up at the beginning of this study may be summarized as follows:

First, it is possible to determine a transverse and a frontal plane of the body which pass through the center of gravity. These planes may be determined without changing the position or the posture of the subject, although the exact situation of the body is changed with respect to the axis of the earth.

Second, the position of the center of gravity is expressed in terms of its linear distance from certain fundamental landmarks. The transverse plane is located as a linear distance from the plane which passes through the soles of the feet. The frontal plane is similarly located as a linear distance from a flat surface upon which the subject lies. By making other bodily measurements, it is possible to orient the center with respect to other anatomical landmarks. In a living subject such a definition of the location of the center must necessarily be sufficient; in a dead body the actual anatomical situation may be found by cutting sections through the body or by dissection.

Third, the method may be applied with equal facility to either living or dead subjects. The method can also be applied to subjects of any age, from infancy to adulthood.

Fourth, by means of this apparatus it is possible to determine the position of the transverse plane of gravity with the same precision as it is possible to determine the linear body measurement or standing height. The frontal plane can be determined as precisely as sitting height can be measured. The time required to determine the center of gravity is less than five minutes and only the very minimum of cooperation of the subject is necessary.

Material

The material for this paper consists of a series of measurements upon 1,172 living subjects - 596 males, and 576 females - whose ages range from birth to 20 years, and upon 18 fetal cadavers having body lengths of 25 to 55 cm. This material was collected in Minneapolis and St. Paul, Minnesota,

and Mooseheart, Illinois. The collection of data was begun in the spring of 1927 and completed in the fall of 1929. The measurements taken were selected with special reference to their application in this particular study and include certain external dimensions of the body, as well as determinations of the position of the transverse and frontal planes of gravity. With these measurements it is possible to locate the center of gravity anatomically, to correlate various dimensions with the position of the center, to reconstruct the body form of any individual or of any composite group, and to make other comparisons and analyses.

The determinations of the two planes of gravity were made according to the procedure already described. A record was thus obtained of the distance of the transverse plane of gravity above the soles, and that of the frontal plane from the back, as measured in two inclined positions.

The other dimensions and data recorded for each individual, and the methods of obtaining them, are summarized briefly as follows:

Age. The age of each subject was determined to the nearest month and recorded in years and months. For example, all children between the ages of 9 1/2 and 10 1/2 months were grouped as 10 months of age.

Weight. The weight of the body was required for the calculation of the center of gravity and was taken as described in the discussion of methods. The weights of the small children were obtained by means of a small 23 kg. scale used with the original apparatus. This scale was graduated by 25 gm. intervals and readings were estimated to the nearest 10 gm. The weight of the body was recorded in kilograms. The weights of the older subjects were obtained by means of a large 250 lb. scale used when the apparatus was changed. Weights were read to the nearest 1/8 lb. and avoirdupois weights were then converted to metric equivalents and also recorded in kilograms. All weights recorded are of nude subjects with the exception of those for girls over 9 years of age. These older girls were clothed in light cotton swimming suits which weighed, quite uniformly, 0.25 kg. Corrections for the weight of these suits have been made in all analyses except in the actual computations of the center of gravity.

Length. Measurement of the crown-heel, or vertex-planta, dimension was made by means of a measuring rod attached to the gravity apparatus. This measurement, as well as measurements of shoulder and pubic heights, and arm and leg lengths, was made with the subject in the same supine position upon the apparatus as that employed for the actual center of gravity

determinations. The details of this position have been described and it is only necessary to repeat here that the feet were placed firmly against the footboard. The pointer of the slider-arm of the measuring rod was placed very lightly upon the uppermost point of the crown to establish the upper end-point of the measurement.

Pubic height. This dimension is the horizontal linear distance from the plantar surface to the soft tissues directly over the superior anterior border of the symphysis pubis in the midline.

Leg length. This dimension is the horizontal linear distance from the plantar surface to the superior external border of the greater trochanter. In every case the measurement was made to the left trochanter.

Arm length. The length of the arm was determined indirectly in this study. The linear distance from the plantar surface to the tip of the third digit of the left hand, the medio-plantar distance, was measured. This value was subtracted from shoulder height (the standard acromion-planta length) and the remainder recorded as the length of the arm.

Stature. This dimension was taken in the manner described by Hrdlička ('20) and was recorded for all children who were able to stand erect. Measurements of most of the young children were made by means of an anthropometer graduated in metric units and set into a large concrete base. All of the older subjects and a few of the younger ones were measured by means of an especially constructed upright anthropometer graduated in English units of length. Measurements were made to the nearest 1/8 in., converted into metric equivalents, and recorded in centimeters.

Sitting height. This dimension is a trunk, or crown-rump, length; it was determined according to the method described by Hrdlička ('20) for obtaining sitting height. For all cases a uniform seat 44 cm. in height and the anthropometers for the determinations of stature were used. All measurements were converted into centimeters. In very young infants this measurement was made by means of a small anthropometer with the subject supine. In the latter cases the distance between the vertex and the ischial tuberosities was recorded as sitting height.

Anteroposterior diameter of chest. This diameter was taken at the level of the apex of the costal angle as the straight-line distance between the xiphisternal junction and the skin of the back in the midline. Care was taken to maintain the caliper in a horizontal plane. End-points were marked with moderate pressure and the readings taken at the midpoint between normal inspiration and expiration.

Transverse diameter of chest. The transverse diameter of the chest was measured in the same horizontal plane as the anteroposterior diameter. Similarly, moderate pressure was used to establish the margins of the chest and the measurement was taken at the midpoint of normal respiratory motion.

Anteroposterior diameter of pelvis. This dimension represents the standard external conjugate, or sacro-pubic, diameter and was taken as the linear distance between the soft tissues over the upper margin of the symphysis pubis and the soft tissues directly over the fossa below the spine of the last lumbar vertebra. Firm pressure was employed to mark the end-points of this measurement.

Transverse diameter of pelvis. The standard intercristal diameter was taken for this dimension. It was represented as a straight-line measurement, in the transverse plane, between the widest portion of the iliac crests. The points of the caliper were placed on the soft tissues over the outer lips of the crests and moved dorsally and ventrally until the widest point was found. Moderate pressure was used to establish the end-points of the measurement.

All measurements were of nude subjects except for the older girls who were clothed as described above in light-weight swimming suits. No correction of the diameters was made for the effect of this clothing. In view of the large experimental error of these measurements the effect of this clothing was considered negligible.

It was not possible to obtain the complete series of measurements of the entire group of 1200 individuals. However, age, stature or length, weight, and the planes of gravity were obtained in every case, and all the measurements were obtained for approximately 80 per cent of the group.

Subjects

This attempt to study the center of gravity during the whole of the developmental period required the collection of subjects from many different sources. The institutions and organizations which have cooperated in furnishing subjects, and a brief description of the data obtained from each source, are as follows:

The Institute of Child Welfare, University of Minnesota. The Institute of Child Welfare was of great help in the development of this research program. All of the early experimentation with methods and apparatuses was carried on there and the Institute bore most of the expense of the project. The nursery school division furnished subjects during a year spent in preliminary investigation. The nursery school and kindergarten

divisions also supplied nearly the entire group of children between the ages of 2 and 6 years. In addition, a special infant study sponsored by the Institute furnished a group of infants under one year of age.

The City of Childhood, Mooseheart, Illinois. This large orphanage of the Loyal Order of Moose was of great service in the prosecution of this program. The gravity device was sent to Mooseheart where the writer was given almost unlimited facilities with which to study normal children. A very large proportion of the measurements described here were made at this institution upon a group of 1000 children. The age range of these subjects extended from approximately 2 to 20 years.

The Salvation Army Maternity Home, St. Paul, Minnesota. A group of 12 infants whose ages ranged from 1 week to 3 months was studied.

The Jean Martin Brown Home for Children, St. Paul, Minnesota. This home furnished a group of 15 children ranging from 1 month to 9 years in age.

The Pediatric Department at the Minnesota University Hospital. A few normal children were obtained from the pediatric wards of the hospital.

The Department of Pathology and the Department of Obstetrics and Gynecology at the University of Minnesota. An attempt was made to extend this study into the prenatal period in order to determine, if possible, any change in the position of the center of gravity before or at the time of birth. Eighteen fetuses, with crown-heel measurements ranging from 25 cm. to 55 cm., were obtained through the courtesy of these departments, and each was examined as soon as possible. Each body was placed upon the apparatus in the supine position with legs and arms extended and tied into position in order to insure uniform posture. The planes of gravity were then determined by precisely the same procedure as that employed for living subjects.

In addition to these sources of material there were a few children who were brought individually to the laboratory where determinations were made.

Among the live subjects, in this study only those that appeared normal were used. No physical examination was made to ascertain "normality" but the entire series was collected with the view of obtaining a sample of the average population excluding the obviously pathological.

All subjects were Caucasian, but no records were taken of parentage, nationality, or occupational status. The nearly 200 individuals examined in St. Paul and Minneapolis furnished a fair cross-sectional sample of the population of that vicinity. A

Table 7

Distribution of living individuals with respect to geographic origin

State	Males	Females	Both sexes
Arkansas	0	3	3
Arizona	1	3	4
California	15	6	21
Colorado	3	4	7
Connecticut	4	2	6
Florida	4	8	12
Georgia	1	0	1
Idaho	5	5	10
Illinois	82	62	144
Indiana	40	42	82
Iowa	12	12	24
Kansas	12	8	20
Kentucky	5	2	7
Louisiana	3	2	5
Maine	3	3	6
Maryland	3	1	4
Massachusetts	6	7	13
Michigan	6	7	13
Minnesota	107	119	226
Missouri	4	2	6
Montana	3	4	7
Nebraska	2	1	3
New Hampshire	7	3	10
New Jersey	9	12	21
New Mexico	0	1	1
New York	25	14	39
North Carolina	6	7	13
Ohio	31	23	54
Oklahoma	2	6	8
Oregon	3	7	10
Pennsylvania	103	117	220
Rhode Island	3	1	4
South Carolina	1	1	2
South Dakota	4	1	5
Tennessee	3	3	6
Texas	1	1	2
Utah	8	10	18
Vermont	2	3	5
Virginia	6	9	15
Washington	7	10	17
West Virginia	24	20	44
Wisconsin	20	19	39
Wyoming	9	5	14
Total	596	576	1172

large portion of the Minnesota group were of Scandinavian or German descent. Many of the subjects obtained from the University district were from the upper socioeconomic classes, but those from the orphanages were generally from the lower occupational groups.

The children studied at Mooseheart were largely from the lower economic strata. The nationalities of this group of children were extremely varied and practically every European stock was well represented. Nearly every section of the United States sends orphans to this institution. Although no detailed classification was possible, the general geographic distribution, as regards the part of the United States in which the subjects originally lived, is shown in Table 7. The table includes the data actually collected in Minnesota. The wide geographic distribution indicates, to some extent, the degree to which this sample represents a general cross-section of the population of the United States.

The distribution of the subjects according to age and sex is shown in Table 8. Age, in this instance, was divided into yearly intervals. An individual's age was assumed to change on his birthday; for example, all subjects from 5 up to 6 years of age were classified in the 5-year-old group. All fetal cases were placed in the "prenatal" group.

The distribution of this material shows that few subjects in the first two years of life were obtained. Some difficulty was experienced in getting such children, especially in the group between 1 and 2 years of age. No organization was found from which they might be available, and it seemed necessary, therefore, to bring most of them individually into the laboratory. That procedure was not satisfactory. In many instances the child became so frightened that it was impossible to make a careful examination. All questionable cases were rejected. Those few individuals who do represent this group were carefully measured, however, and the data are, therefore, considered reliable.

It will be noted that the period about the time of puberty is well represented. A definite attempt was made to obtain as many cases as possible in this group in order that changes associated with puberty, especially sex changes and differences, might be more clearly brought out.

While it is not assumed that this group of approximately 1,200 children represents a true random sample of the developing child in the United States, it is believed that a sufficiently large and diverse group has been studied to establish preliminary standards and "norms" of the position of the center of gravity during the growing periods.

In this paper only part of the material actually collected will be used since the analysis is limited to consideration of the observations upon age, stature, weight, sitting height, pubic height, arm and leg lengths, anteroposterior diameters of chest and pelvis, and the distances of the center of gravity above the soles and from the back. Tables 9 and 10 show the original observations upon 596 living males and 576 living females. Observations upon the dead fetuses are given in Table 11.[3]

Table 8

Distribution of cases with respect to age

Age interval (yr.)	Males	Females	Both sexes
Prenatal	8	10	18
0 - 1	17	17	34
1 - 2	11	3	14
2 - 3	16	21	37
3 - 4	27	24	51
4 - 5	34	27	61
5 - 6	40	27	67
6 - 7	21	22	43
7 - 8	41	24	65
8 - 9	32	33	65
9 - 10	37	33	70
10 - 11	36	37	73
11 - 12	53	40	93
12 - 13	53	46	99
13 - 14	41	57	98
14 - 15	30	52	82
15 - 16	32	46	78
16 - 17	35	30	65
17 - 18	20	28	48
18 - 19	16	5	21
19 - 20	2	4	6
20 - 21	2	0	2
Total	604	586	1190

[3]*For convenience, Tables 9, 10 and 11 are placed at the end of the paper.*

Findings and Discussion

Position of Transverse Plane of Gravity

There are, in general, three more or less standardized methods of presenting and analyzing the type of material obtained in this study. The first and oldest method involves the use of an index or percentage to express the relationship between variable factors. The second method employs various indices of correlation to establish degrees of concomitance and association. The third method interprets relationships by means of graphic and analytic expressions. The efficacy of each of these procedures will be shown in an introductory study of the position of the transverse plane of gravity as it is related to total body length.

Since E. and W. Weber in 1836 made the first quantitative measurement upon the center of gravity, nearly every investigator of this problem has expressed the distance of the center of gravity from the soles in the form of an index or a per cent of the total body length. Many previous studies do not definitely state the body length dimension used in the calculation of the index or percentage height. In certain instances the linear crown-heel dimension measured in the supine position was used, in others, the stature, or standing height, dimension measured in the erect position was used. The well-known differences between these measurements make accurate comparisons difficult.

It is necessary to establish definitely the length dimension to be used in the calculation of the index, and this is especially necessary if precise comparisons are to be made within the whole range of the developmental period.

Boyd has shown the reliability of various length measurements and has clearly indicated that the standing height or stature dimension furnishes the best measurement of the total linear size of the body. It cannot, of course, be employed in the measurement of infants. The determination of any total length measurement in infancy, however, involves the straightening out of the legs against active flexion. This flexion tends to decrease the magnitude of any length dimension and raises the question of whether a measurement taken in the supine position upon infants is comparable with similar measurement upon older children where the flexion tendency has disappeared. It seems justifiable to conclude that part, at least, of the usual difference between standing height and crown-heel length may be counteracted by this flexion of the legs. Accordingly, it was finally decided to use the standing height dimension for all children in whom it was possible to obtain a measure in the erect position, and to use the crown-heel dimension taken in the

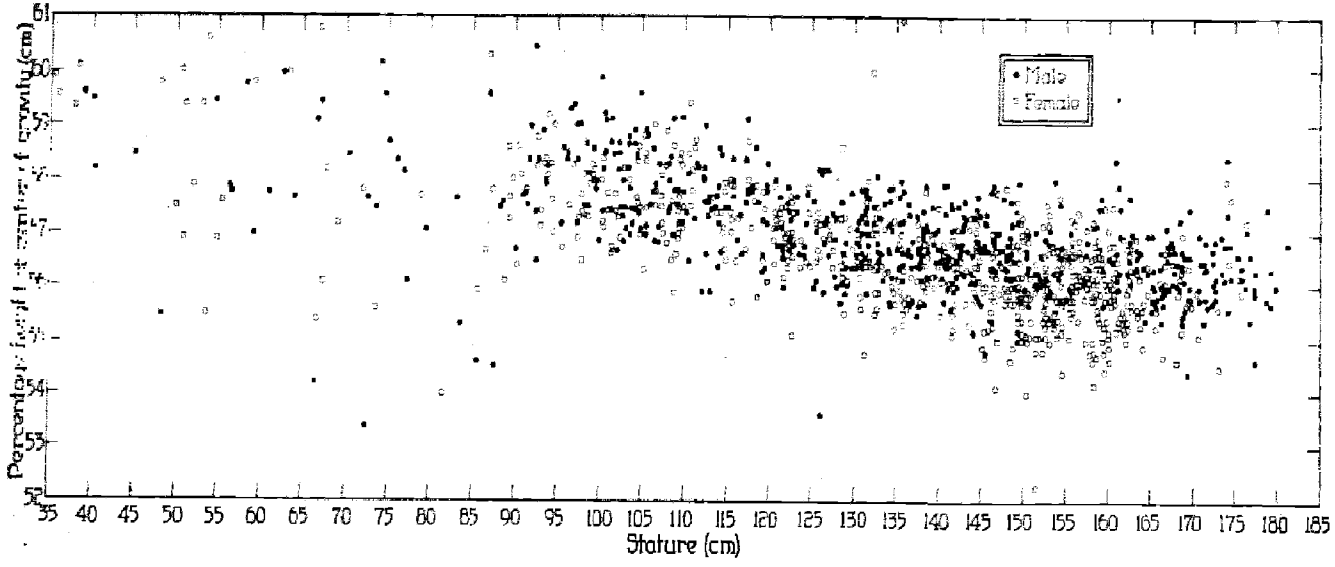

Figure 4. The index or percentage height of the center of gravity plotted against stature, from approximately the sixth fetal month to maturity.

supine position for the remainder of the group. These measurements are simply combined and the subsequent use of the term 'stature' in this paper will be understood to mean the combination of these two dimensions whenever it is necessary to use a body length measurement for the whole of the developmental period. This procedure is doubtless open to criticism but it has been adopted because some compromise is necessary, and it is justified on the grounds that it seems to introduce the least amount of error. The index, or percentage height, of the center of gravity is thus obtained by the following formula:

$$\frac{\text{Distance of center of gravity from soles}}{\text{Stature (standing height where possible and crown-heel in infants)}} \times 100 = \text{Index or percentage height.}$$

In Figure 4 the index, or percentage height, of the center of gravity is plotted on the ordinate and stature on the abscissa. In this graph stature is used in the same sense as for the calculations of the ratio. The entire series of 1200 observations, including the 18 prenatal cases, is shown in this graph. The belief of early workers, that the height of the center of gravity is closely related to body length, is substantiated. The index is fairly constant during the whole of the developmental period from about the sixth fetal month to maturity. This material shows considerable variability before the first two years of postnatal life; after that time the variability is reduced and remains low during the rest of the growing period. The greater dispersion of the first period is probably due to the greater experimental error where the actual variability of the material is overshadowed by the errors of measurement.

Despite the fluctuations in the earlier years almost the entire series is included between the indices 54.5 and 59.5, and a rough count shows that 1121 of the 1200 cases are included between 55.0 and 59.0, a range of 4 per cent. The notable constancy of this index is thus shown by the fact that approximately 95 per cent of the entire group extend over a range of only 4 per cent.

Review of the literature has indicated that similar findings are reported by other investigators and that in this respect the results of the present work are well in accord with the data already published upon the problem.

Further study of Figure 4 shows a definite trend even within the small range of 4 per cent. The trend is not clean-cut until the second year of postnatal life but at that time it becomes well established and is definite throughout the remainder of the growing period. As stature increases from approxi-

mately 85 cm. to 180 cm. the relative height of the center of gravity definitely decreases. Analysis of this change indicates that it is dependent upon two factors. Either the rate of upward growth of the center of gravity is changing, and it is not keeping pace with the growth of the body, or a residual factor is present which makes the rate of growth of the center appear to slow down even though its actual rate remains the same. Perhaps both of these factors are jointly responsible. The expression of the height of the center of gravity as a ratio, however, will not permit the analysis of this factor, nor will this method give further fundamental information concerning the relationship of the two variables.

Certain measures of correlation which may be employed to establish relationships have been tested in this particular problem. The Pearsonian coefficient, r, was calculated for stature and the height of the center of gravity for a sample group of 200 children between the ages of birth and seven years. In this case r was found to equal $+.991 \pm 0.003$. The interpretation of this high correlation is difficult and indicates to some extent the applicability of measures of correlation to the study. In this case r shows an obvious high degree of concomitance or association which is essentially due to the third factor, time. The actual quantitative relationship between height of the center of gravity and stature is not expressed by the measures of correlation, except, of course, if r be used to derive the least squares' regression line. If this latter use is made of r, essentially the same results will be obtained as by the more direct method to be described later.

The extension of the correlation method to measures of partial correlation does not seem warranted because there are so few cases and because the progression is so steep that even though a small interval is chosen it will not eliminate the time factor.

The application of Harris' ('09) "the correlation between a variable and the deviation of a dependent variable from its probable value" does add, however, another point strictly in the terms of correlation measurement. It is obvious that the height of the center of gravity is dependent upon the height of the body and that the requirements for this coefficient are fulfilled. The calculation of this coefficient between stature and the deviation of the height of the center of gravity from its probable value, upon the sample group of 200 children, gives the value $-.28 \pm .05$. The interpretation of this negative coefficient leads to the same conclusions that are brought out by other methods: that the relative height of the center decreases with the increase in stature. Like the index method, however, it does not permit of a definite

quantitative statement of the deviation.

The third method to be applied to this phase of the problem is essentially a graphic and analytical method that involves the derivation of a mathematical equation to express the relationship between variables.

Figure 5 is a field graph showing the actual distance of the center of gravity from the soles plotted against stature. Similar to Figure 4, this graph extends over the whole of the developmental period from the sixth fetal month to maturity. The graph shows a very striking rectilinear relationship between the two measurements. The variability about the line of progression is notably low and there is certainly no situation along the progression which would indicate more than random deviation from linearity.

This method of attack is carried a step further in Figure 6 (insert in Figure 5) which shows the mean distance of the center of gravity from the soles for each 5 cm. interval of stature plotted against stature. In the analysis males and females have been averaged separately in order that the presence of sex differences may be ascertained. In Tables 12 and 13 are shown the means with their probable errors, standard deviations, and coefficients of variability for the males and females, respectively. In Table 14 the weighted means and measures of variability are shown for both sexes combined. The rectilinearity of relationship between the height of the center of gravity and stature is also clearly shown from the plotted means (Figure 6). A straight line, fitted by means of the method of Concon ('27), and Birge and Shea ('27), shows that the relationship between stature and the height of the center of gravity for both sexes may be expressed by the following formula:

$$y = .557x + 1.4 \text{ cm.}$$

where y equals the distance of the center of gravity from the soles and x the stature of the body.

This method of analysis furnishes a precise description of the relationship between stature and the distance of the center from the soles. The fact that a straight line gives the best representation of the relationship shows that there is no change in the rate of growth of the center compared with growth in length and that a constant expresses the rate of growth throughout the whole of the developmental period. The small decrease in the index may now be definitely and precisely explained as due to the small residual constant of 1.4 cm. (the y-intercept of the regression formula).

In order to present this finding in more graphic form a

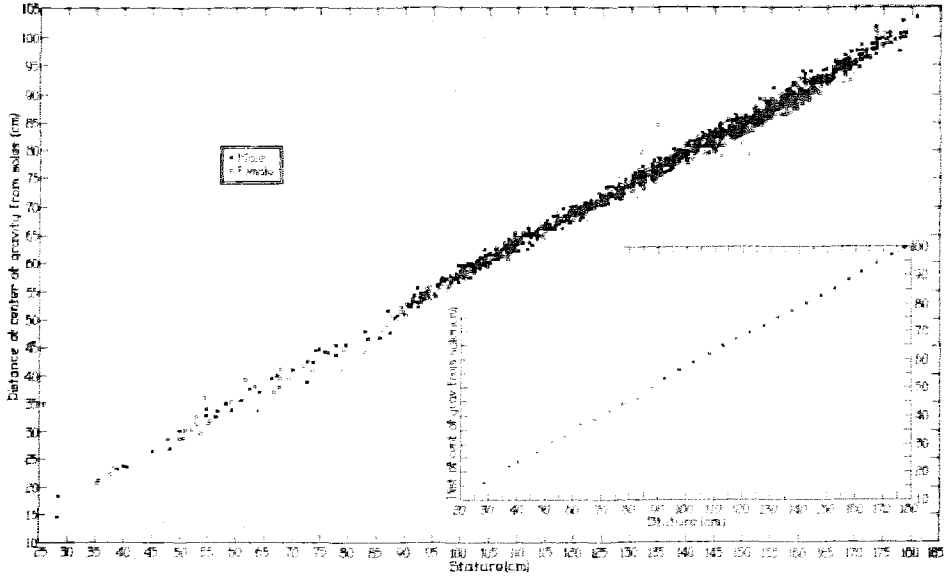

Figure 5. The distance of the center of gravity from the soles plotted against stature, from approximately the sixth fetal month to maturity.

Figure 6 (insert). The relationship between the distance of the center of gravity from the soles and stature. The dots in this graph mark the intersection of the mean height of the center of gravity and the mean stature for each 5 cm. interval of stature. The fine lines above and below each dot represent three times the probable error of the mean height of the center of gravity; the fine lines lateral to each dot represent three times the probable error of the mean stature for the interval.

Table 12

Means and variability, for intervals of stature, of height of transverse plane of gravity from soles

(males)

Interval of stature (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
25- 30	2	16.5 ± 0.86	0.18	10.91
30- 35	0	- -	-	-
35- 40	1	23.3 ± -	-	-
40- 45	2	23.75 ± 0.06	0.06	2.53
45- 50	2	26.60 ± 0.43	0.90	3.38
50- 55	3	32.23 ± 0.55	1.42	4.41
55- 60	5	33.42 ± 0.30	0.91	2.72
60- 65	3	36.57 ± 0.47	1.21	3.31
65- 70	2	39.70 ± 0.09	0.20	1.40
70- 75	6	42.27 ± 0.60	2.17	5.13
75- 80	5	44.52 ± 0.24	0.80	1.80
80- 85	2	47.05 ± 0.57	1.20	2.55
85- 90	5	49.50 ± 0.74	2.20	4.44
90- 95	15	53.47 ± 0.21	1.20	2.34
95-100	18	56.82 ± 0.15	0.92	1.62
100-105	35	59.62 ± 0.12	1.09	1.83
105-110	27	62.31 ± 0.15	1.16	1.86
110-115	27	64.87 ± 0.15	1.18	1.82
115-120	25	67.45 ± 0.14	0.99	1.47
120-125	26	69.93 ± 0.13	0.95	1.36
125-130	29	72.30 ± 0.17	1.39	1.92
130-135	44	75.37 ± 0.11	1.10	1.46
135-140	47	77.84 ± 0.10	1.04	1.34
140-145	55	80.68 ± 0.11	1.26	1.56
145-150	48	83.54 ± 0.12	1.27	1.52
150-155	39	85.97 ± 0.13	1.18	1.37
155-160	18	89.24 ± 0.22	1.41	1.58
160-165	25	92.16 ± 0.14	1.05	1.13
165-170	45	94.14 ± 0.13	1.30	1.38
170-175	31	97.25 ± 0.18	1.51	1.55
175-180	16	99.67 ± 0.22	1.29	1.29
180-185	1	103.1 ± -	-	-

Table 13

Means and variability, for intervals of stature, of height of transverse plane of gravity from soles

(females)

Interval of stature (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
25- 30	0	- -	-	-
30- 35	0	- -	-	-
35- 40	4	22.03 ± 0.40	1.20	5.44
40- 45	0	- -	-	-
45- 50	1	28.70 ± -	-	-
50- 55	8	30.95 ± 0.53	2.23	7.21
55- 60	3	32.83 ± 0.88	2.26	6.88
60- 65	2	38.60 ± 0.40	0.85	2.20
65- 70	5	37.00 ± 0.69	2.28	6.16
70- 75	2	41.25 ± 0.23	0.49	1.88
75- 80	1	44.80 ± -	-	-
80- 85	1	44.10 ± -	-	-
85- 90	9	50.78 ± 0.37	1.63	3.21
90- 95	16	53.93 ± 0.21	1.25	2.32
95-100	15	56.33 ± 0.18	1.03	1.83
100-105	21	58.97 ± 0.18	1.22	2.06
105-110	31	62.20 ± 0.13	1.08	1.73
110-115	16	65.13 ± 0.11	0.66	1.01
115-120	18	67.02 ± 0.20	1.25	1.86
120-125	30	69.67 ± 0.12	0.94	1.35
125-130	25	72.46 ± 0.13	0.99	1.37
130-135	38	74.94 ± 0.15	1.35	1.80
135-140	30	77.67 ± 0.22	1.75	2.25
140-145	40	80.37 ± 0.14	1.31	1.63
145-150	54	82.78 ± 0.15	1.58	1.91
150-155	60	85.28 ± 0.15	1.76	2.06
155-160	70	88.37 ± 0.10	1.22	1.38
160-165	57	90.47 ± 0.12	1.30	1.43
165-170	18	93.83 ± 0.22	1.36	1.45
170-175	6	97.12 ± 0.81	2.95	3.04
175-180	3	99.20 ± 0.51	1.31	1.32
180-185	-	- -	-	-

Table 14

Means and variability, for intervals of stature, of height of transverse plane of gravity from soles

(both sexes)

Interval of stature (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
25- 30	2	16.50 ± 0.86	1.80	10.90
30- 35	0	-	-	-
35- 40	5	22.28 ± 0.31	1.02	4.58
40- 45	2	23.75 ± 0.03	0.06	0.25
45- 50	3	27.30 ± 0.64	1.64	6.01
50- 55	11	31.30 ± 0.42	2.07	6.61
55- 60	8	33.20 ± 0.31	1.32	3.97
60- 65	5	37.38 ± 0.27	0.90	2.41
65- 70	7	39.20 ± 0.33	1.28	3.27
70- 75	8	42.02 ± 0.43	1.79	4.26
75- 80	6	44.57 ± 0.19	0.70	5.71
80- 85	3	46.00 ± 0.51	1.31	2.85
85- 90	14	50.32 ± 0.29	1.61	3.20
90- 95	31	53.71 ± 0.14	1.17	2.18
95-100	33	56.60 ± 0.11	0.91	1.61
100-105	56	59.38 ± 0.10	1.09	1.84
105-110	58	62.25 ± 0.10	1.10	1.77
110-115	43	64.97 ± 0.10	1.00	1.54
115-120	43	67.27 ± 0.11	1.07	1.59
120-125	56	69.79 ± 0.09	0.95	1.36
125-130	54	72.37 ± 0.11	1.21	1.67
130-135	82	75.17 ± 0.09	1.20	1.60
135-140	77	77.77 ± 0.12	1.49	1.92
140-145	95	80.55 ± 0.09	1.27	1.58
145-150	102	83.14 ± 0.09	1.40	1.68
150-155	99	85.55 ± 0.07	1.02	1.19
155-160	88	88.55 ± 0.09	1.23	1.39
160-165	82	90.99 ± 0.07	0.98	1.08
165-170	63	94.05 ± 0.11	1.23	1.31
170-175	37	97.23 ± 0.19	1.72	1.77
175-180	19	99.60 ± 0.19	1.23	1.24
180-185	1	103.10 -	-	-

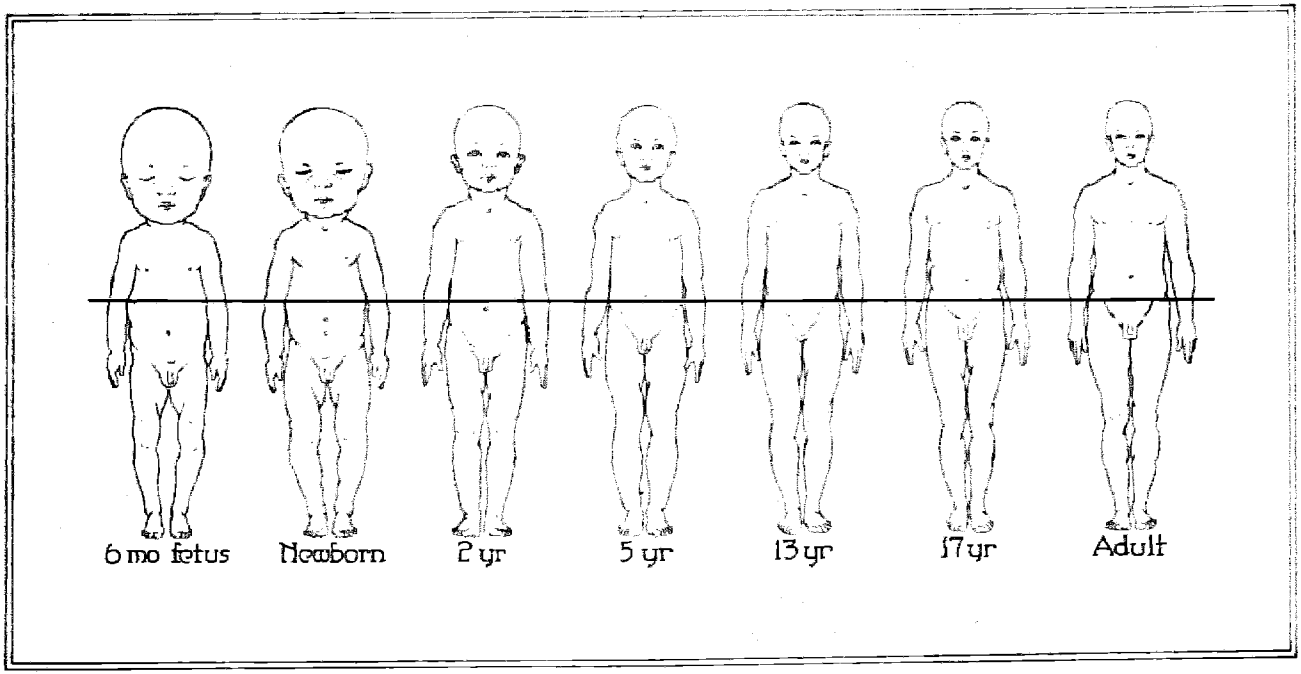

Figure 7. Outline drawings of the ventral aspect of the body at intervals from the sixth fetal month to maturity. Body lengths are reduced to the same scale and the transverse plane of gravity is represented by the transverse line.

series of outline figures illustrating the external form of the body from the sixth fetal month to maturity is shown in Figure 7. In drawing these figures the measurement of stature has been reduced to a common scale and thus a single line may be calculated and drawn through the outlines to show the position of the transverse plane of gravity. The figures illustrate diagrammatically the changes in the form and contour of the body which are largely responsible for the shift of the transverse plane of gravity. The actual anatomic location of this plane and the structures involved in its change of position will be discussed later.

The analytic method readily permits the determination of sex differences. Table 15 shows the differences and probable errors of the differences between the mean heights of the center of gravity at 5 cm. intervals of stature for males and females. The differences and probable errors are illustrated graphically in Figure 8. The solid bar represents the absolute difference between means and the open bar its probable error. The positive side of the histogram indicates that the distance of the center of gravity from the soles for males is greater, and the negative side, that the distance for females is greater. It is shown that at 18 intervals the center is higher in males and at 5 intervals it is higher in females. In only four instances are these differences significant, i.e., three, or more, times the probable error of the difference. The actual meaning of these findings is not definite although it is apparent that for the period during which stature ranges from 145 to 165 cm. the center of gravity is slightly higher in males than it is in females.

The determination of significant differences in this manner introduces the possibility of a difference in the mean stature of the two sexes within a given interval. In Tables 16 and 17 the mean stature for each 5 cm. interval, the probable error of the mean, the standard deviation, and coefficient of variability are given for the males and females, respectively. A comparison of the means for the intervals between 145 and 165 cm., the range over which the sex differences appeared significant, shows that there is no significant difference in the stature of the males and females, except for the interval from 160 to 165 cm. In this interval the mean stature of the males is 162.54 cm. and the mean for the females is 161.83 cm. - a difference of 0.71 cm. The effect of this difference in stature has been determined by means of the analytical equation derived above. After the correction has been made for the differences in stature the difference between the mean height of the center of gravity in the two sexes is found to be 1.29 cm. rather than 1.69 cm. The corrected value is recorded in Table 15 and Figure 8. Despite

Table 15

Significance of sex differences of height of center of gravity as determined by probable errors of means for intervals of stature

Interval of stature (cm.)	Diff. of means $M_{m.} - M_{f.}$ (cm.)	P. E. of diff. (cm.)	Ratio $\frac{\text{Diff.}}{\text{P. E. of diff.}}$
35- 40	+1.27	-	-
40- 45	-	-	-
45- 50	-2.10	-	-
50- 55	+1.28	0.76	1.7
55- 60	+0.59	0.93	0.6
60- 65	-2.03	0.62	3.2
65- 70	+0.70	0.70	1.0
70- 75	+1.02	0.64	1.5
75- 80	-0.28	-	-
80- 85	+2.95	-	-
85- 90	-1.28	0.83	1.5
90- 95	-0.46	0.30	1.5
95-100	+0.49	0.23	2.1
100-105	+0.65	0.22	3.0
105-110	+0.11	0.20	0.6
110-115	-0.26	0.19	1.4
115-120	+0.43	0.24	1.7
120-125	+0.26	0.18	1.3
125-130	-0.16	0.21	0.7
130-135	+0.43	0.19	2.3
135-140	+0.17	0.24	0.7
140-145	+0.31	0.18	1.4
145-150	+0.76	0.19	3.9
150-155	+0.69	0.20	3.4
155-160	+0.87	0.24	3.6
160-165	+1.29	0.18	7.2
165-170	+0.31	0.26	1.2
170-175	+0.13	0.99	0.1
175-180	+0.47	0.56	0.8
180-185	-	-	-

Table 16

Means and variability of stature

(5 cm. intervals)

(males)

Range (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
25- 30	2	28.45 ± 0.03	0.06	0.22
30- 35	0	- -	-	-
35- 40	1	39.00 -	-	-
40- 45	2	40.35 ± 0.24	0.49	1.22
45- 50	2	46.70 ± 1.08	2.26	4.84
50- 55	3	53.40 ± 0.98	2.51	4.70
55- 60	6	57.23 ± 0.32	1.15	2.00
60- 65	3	62.53 ± 0.62	1.60	2.57
65- 70	3	67.30 ± 0.24	0.62	0.93
70- 75	6	73.00 ± 0.44	1.61	2.21
75- 80	5	77.44 ± 0.45	1.49	1.92
80- 85	4	83.13 ± 0.42	1.25	1.50
85- 90	5	87.32 ± 0.36	1.20	1.38
90- 95	16	92.04 ± 0.20	1.19	1.30
95-100	18	97.55 ± 0.20	1.28	1.31
100-105	35	102.58 ± 0.16	1.41	1.38
105-110	27	107.78 ± 0.20	1.54	1.43
110-115	27	112.69 ± 0.17	1.28	1.14
115-120	25	157.81 ± 0.19	1.44	0.91
120-125	26	122.41 ± 0.16	1.20	0.98
125-130	29	127.40 ± 0.17	1.36	1.07
130-135	44	132.28 ± 0.15	1.50	1.14
135-140	46	137.26 ± 0.13	1.29	0.94
140-145	55	142.44 ± 0.14	1.57	1.10
145-150	48	147.49 ± 0.14	1.43	0.97
150-155	40	152.56 ± 0.15	1.36	0.89
155-160	18	157.63 ± 0.24	1.48	0.94
160-165	25	162.54 ± 0.18	1.32	0.81
165-170	45	167.75 ± 0.16	1.53	0.91
170-175	31	172.42 ± 0.16	1.32	0.76
175-180	16	177.51 ± 0.24	1.42	0.80
180-185	1	181.60 ± -	-	-

Table 17

Means and variability of stature

(5 cm. intervals)

(females)

Range	Number of cases	Mean and probable error	Standard deviation	Coefficient of variability
(cm.)		(cm.)	(cm.)	(percent)
35- 40	4	36.70 ± 0.51	1.54	4.20
40- 45	0	-	-	-
45- 50	1	48.00 -	-	-
50- 55	8	52.28 ± 0.39	1.63	3.12
55- 60	3	56.50 ± 0.88	2.26	4.00
60- 65	2	62.55 ± 0.51	1.06	1.69
65- 70	5	67.82 ± 0.25	0.83	1.22
70- 75	2	72.75 ± 0.51	1.06	1.46
75- 80	1	77.70 -	-	-
80- 85	1	81.60 -	-	-
85- 90	11	88.19 ± 0.30	1.48	1.68
90- 95	16	92.94 ± 0.26	1.51	1.62
95-100	15	97.84 ± 0.19	1.09	1.11
100-105	21	102.45 ± 0.25	1.69	1.65
105-110	31	107.94 ± 0.18	1.48	1.37
110-115	16	112.79 ± 0.31	1.85	1.64
115-120	18	116.91 ± 0.25	1.58	1.35
120-125	30	122.22 ± 0.15	1.24	1.02
125-130	25	127.61 ± 0.19	1.43	1.12
130-135	38	132.51 ± 0.15	1.33	1.00
135-140	30	137.20 ± 0.17	1.40	1.02
140-145	40	142.50 ± 0.17	1.58	1.11
145-150	54	147.88 ± 0.15	1.61	1.09
150-155	60	152.74 ± 0.13	1.44	0.94
155-160	70	157.50 ± 0.11	1.36	0.86
160-165	57	161.84 ± 0.12	1.40	0.86
165-170	18	167.73 ± 0.27	1.68	1.00
170-175	6	172.45 ± 0.50	1.82	1.05
175-180	3	175.80 ± 0.18	0.46	0.26

the correction, however, the difference between the sexes in this interval remains seven times its probable error.

Three methods of attacking the problem of the relationship between stature and the height of the center of gravity have been discussed. The first of these was the expression of the relation by means of an index. The second method involved the calculation of various measurements of correlation. In the third, an analytical geometric expression was obtained to show the relationship. The relative merits of these methods are important.

The use of the index method is largely responsible for many erroneous conceptions. The materials of Croskey, Dawson, Leussen, Marohn and Wright show essentially the same facts that have been brought out in the present study. The use of the

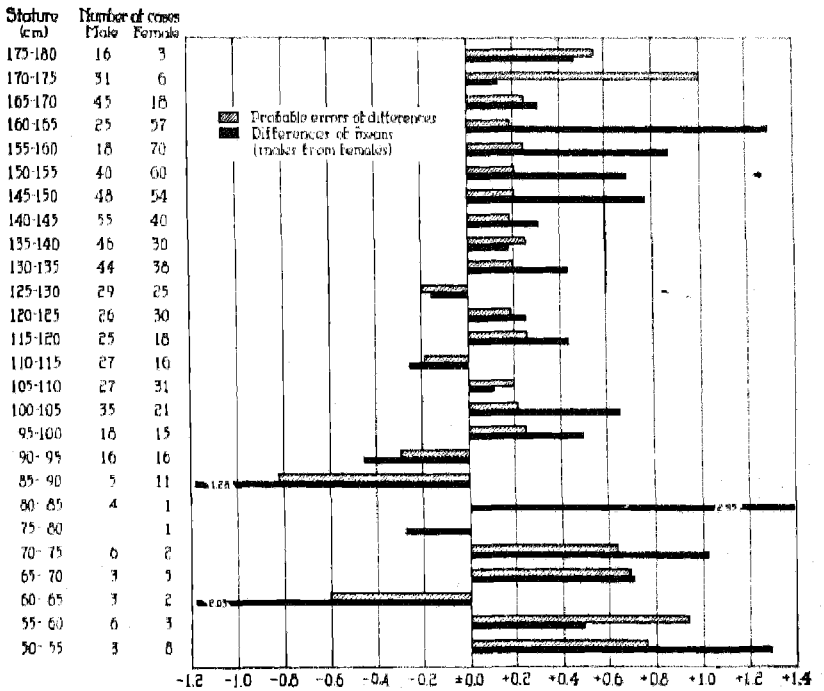

Figure 8. The significance of sex differences of the distance of the center of gravity from the soles, as determined by the differences and probable errors of the means for intervals of stature. The positive side of the scale shows that the distance for males is greater and the negative side that the distance for females is greater.

index, however, so misled these investigators that they definitely stated, "there was no acceptable correlation found between either height or weight and the center of gravity." Their correlations were, of course, made between the relative height of the center of gravity and body length and are questionable from the standpoint of both accuracy and interpretation. In addition, their use of the index not only completely obscured the fundamental relation between stature and the position of the center of gravity, but led them to make an entirely erroneous presentation.

The results of this and previous investigations indicate that the index or per cent method does not furnish the most satisfactory means of handling this material. In this instance the relationship between the height of the center of gravity and stature is quite accurately expressed by the index, but still more precise relationships are obtained by the use of the analytic method.

Further study of the distance of the center of gravity from the soles in respect to other factors has been made.

Figure 9 is a field graph showing both the distance of the

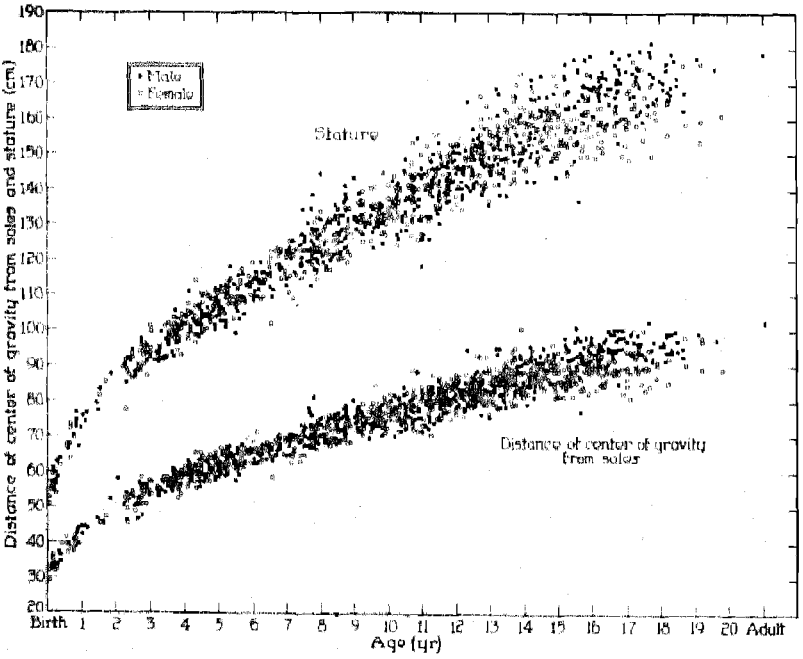

Figure 9. Both stature and the distance of the center of gravity from the soles plotted against age, from birth to maturity.

center above the soles and stature plotted against age. The upper progression follows a curve typical of the postnatal growth of the body in length. The lower progression follows a similar curve showing the growth of the center of gravity in height. Both curves are of the same general type and reflect the very close relationship existent between the two measurements. The variability of stature about its line of progression is representative of the age-length distribution. The variability of the height of the center of gravity about its line of progression is distinctly less than that for stature. Part of this reduction in variability may be explained by the fact that there is less experimental error inherent in determining the position of the transverse plane of gravity than in determining stature. This factor does not account for all of the difference in variability and it is clearly shown that the height of the center of gravity is a very stable measure of the growth of the body. During the first two years of postnatal life the rate of increase in the distance of the center of gravity from the soles is rapid. The rate then gradually decreases and proceeds in a very regular manner during the remainder of the postnatal growth period.

The height of the center of gravity above the soles is plotted against the weight of the body in Figure 10. The curvilinear progression shown in this figure is typical of the relationship between height and weight and again there is a reflection of the close relation between the position of the center of gravity and stature. It is shown, also, that the association between the center of gravity and body weight is not so precise as that between the center of gravity and body length.

A study has been made of the relations of the transverse plane of gravity with respect to other anatomic landmarks. In Figure 11 the trochanter-planta distance is plotted against stature. This is essentially leg length compared with body length, and it is seen that there is a simple rectilinear relationship between the two dimensions. The relationship is very similar to that of the height of the center of gravity and stature, and the question arises whether the height of the center of gravity and the lower extremities grows in the same manner and at the same rate. To ascertain this point, the fitted regression line of the height of the center of gravity upon stature has been drawn upon the field graph of leg length and stature. The slope of the calculated regression line compared with the progression of leg length, shows that the lower extremities are growing at a greater rate than the center of gravity is moving. This more rapid rate of growth of the lower extremities gradually brings the center of gravity closer to the proximal end of the lower limbs. An estimate of the actual changes shows that at birth

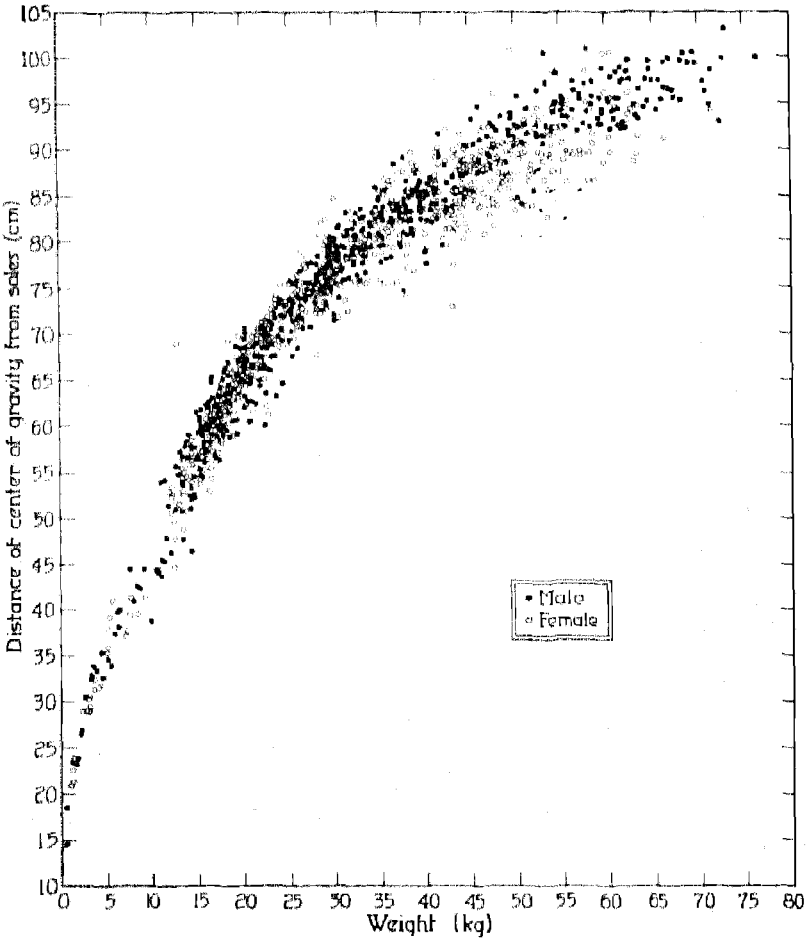

Figure 10. The distance of the center of gravity from the soles plotted against body weight, from approximately the sixth fetal month to maturity.

the center of gravity lies approximately 20 cm. above the trochanters and at maturity this distance has been reduced to 10 cm. A distance of 20 cm. above the trochanters in the newborn body brings the center of gravity into a position relatively high above the legs, approximately to the lower level of the thoracic cavity. A distance of 10 cm. above the trochanters in the adult body brings the center into a position relatively close to the lower extremity, actually, to the approximate level of the

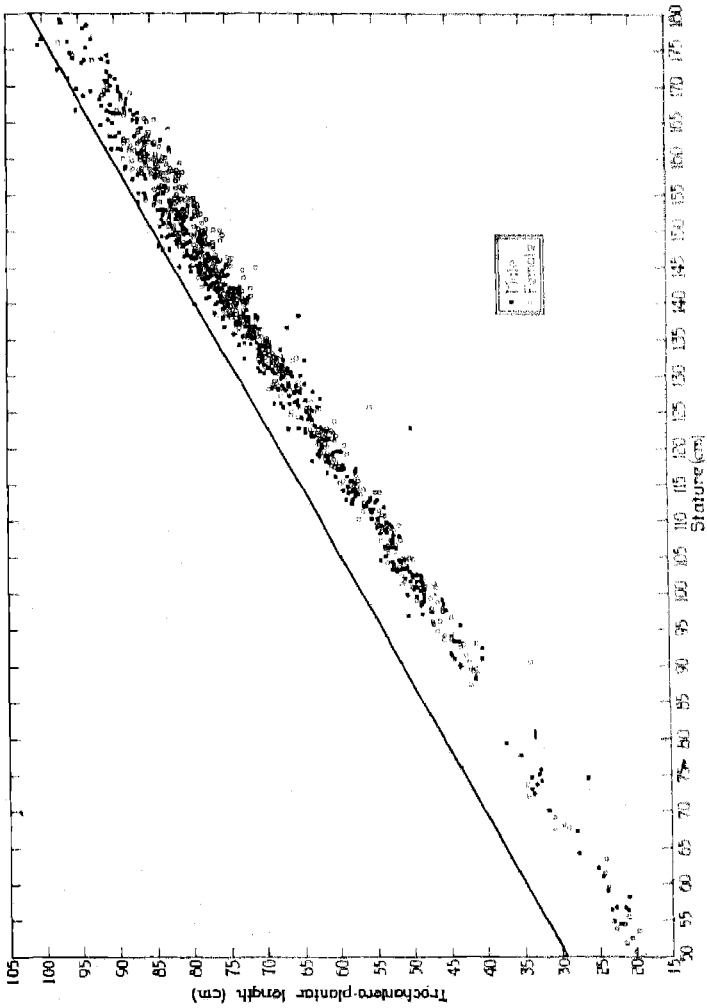

Figure 11. The trochanter-planta length plotted against stature, from birth to maturity. The straight line is the regression line calculated for the distance of the center of gravity from the soles and stature.

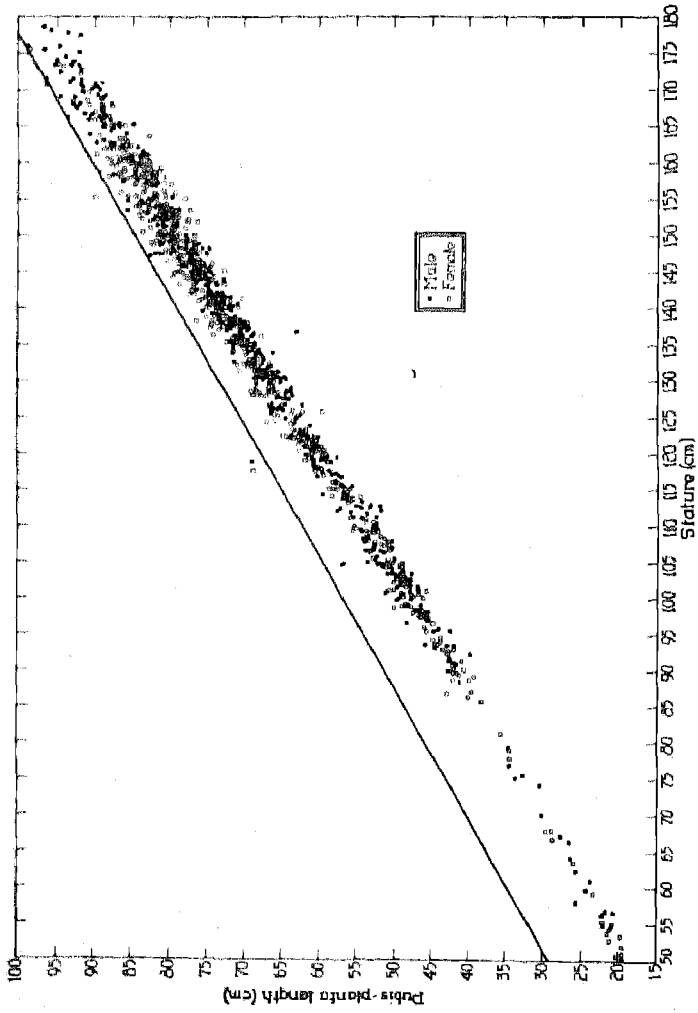

Figure 12. The pubis-planta distance plotted against stature, from birth to maturity. The straight line represents the regression line calculated for the distance of the center of gravity from the soles and stature.

iliac crests. This finding is in accord with the measurements of Meyer who found the center of gravity to lie 9.5 cm. above the point of rotation of the heads of the femora.

These changes in the position of the center of gravity are of interest from the point of view of the mechanics of motor activity. Any movement of the body, and in particular, any movement of locomotion, involves changing the position of the center of gravity in space. From a mechanical standpoint it is well known that the efficiency of energy expended to produce motion is dependent upon the location of the center of mass of the object moved. Greater efficiency is obtained by approximating the center of mass and the moving power. In the human body the assumption of the erect posture has placed the problem of locomotion largely upon the lower extremities. From this point of view, efficiency in locomotion is slowly increased during the developmental period as the center of gravity descends from a position high above the lower extremities to a position in close proximity to the chief motive power in the legs.

The stability of the human body is intimately connected with this problem. The stability of any body is inversely related to the distance of its center of mass from the basis of support. It has been shown, particularly in Figure 5, that the absolute distance of the center of gravity above the soles, or basis of support, increases; therefore, the stability of the body decreases during growth. It has been shown, as well, that the relative height of the center of gravity slightly decreases, which tends to compensate to a very slight extent for the increased distance from the base. From this point of view the adult human body is much more unstable than the infant body. It seems justifiable to believe, however, that the increased mechanical efficiency brought about by the closer proximity of the center of mass and its activating force must compensate for the greater instability. Many factors and forces are involved in such general problems as locomotion, equilibrium and mechanical efficiency, but it is not possible to go into these problems except to indicate further applications of this study.

An investigation similar to that made of the trochanter-planta length has been made for the pubis-planta length. In Figure 12 the pubis-planta length is plotted against stature and the calculated regression line of the height of the center of gravity against stature drawn upon the field graph. Almost the same changes seen in Figure 11 indicate that the trochanter-planta and pubis-planta lengths are practically identical. The transverse plane of gravity in the newborn passes through the trunk approximately 20 cm. above the upper margin of the pubis. During the

remainder of the developmental period this plane descends through the abdomen until it is 10 cm. above the pubis. Although this shift of the plane of gravity appears small, only 10 cm., a marked change is made in the actual anatomic location of the plane. Twenty centimeters above the symphysis in the trunk of the newborn reaches almost to the tip of the xiphoid process, while 10 cm. above the symphysis in the trunk of the adult marks a point relatively close to the upper margin of the pubis itself. Details of the anatomic structures through which this plane moves will be discussed later.

The distance of the transverse plane of gravity from the crown or vertex was calculated by subtracting the distance of the transverse plane above the soles from stature. The relation between this measurement and stature can be analytically expressed by the equation:

$$z = .443x - 1.4 \text{ cm.}$$

where z equals the distance from the center to the crown and x equals stature. This formula was derived by transforming the equation expressing the relationship between the distance of the center of gravity from the soles and stature.

In order to determine the relationship between the lineal growth of the trunk and the position of the transverse plane, the distance of the transverse plane from the crown was plotted against sitting height. Figure 13 is a field graph of this material. It is shown that the simple rectilinear relationship found between the transverse plane and stature does not hold in this case. This progression forms a very shallow "s" curve, which is probably due to the extremely slow growth of the head during postnatal life. In connection with this point, stature has been plotted against sitting height as shown in Figure 14. The same shallow "s" curve which results provides further evidence that the divergence from linearity seen in the previous curve is not due to any change of the fundamental relationship between the height of the center of gravity and stature.

The Position of Frontal Plane of Gravity

Observations upon the distance of the center of gravity from the back present a complex problem. These measurements are shown plotted against stature in Figure 15. The first portion of the curve shows a wide distribution in which there appears a very curious trend. But after stature reaches 90 cm. the variability is markedly decreased and a simple upward trend appears. A more detailed analysis of this material was

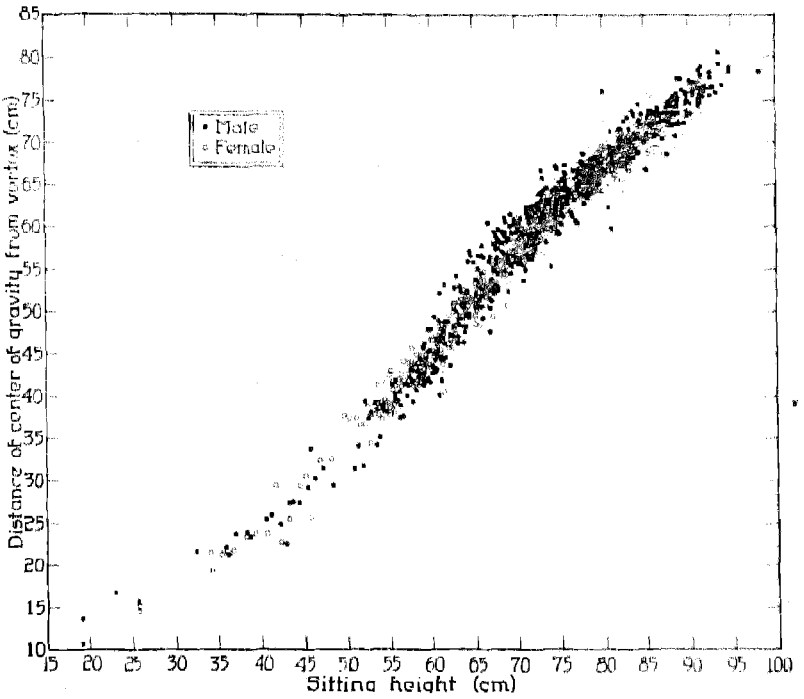

Figure 13. The distance of the center of gravity from the crown plotted against sitting height, from approximately the sixth fetal month to maturity.

made by calculating the means of the distance of the center of gravity from the back for each 10 cm. interval of stature. The sexes have been separated in this analysis and Tables 18, 19, and 20 show the means with their probable errors, standard deviations and coefficients of variability for the males, females, and for the sexes combined, respectively. The means for the sexes combined, together with their probable errors, are plotted against stature in Figure 16. The trends which were not distinctive in the field graph are definitely brought out in this figure. It is demonstrated that this dimension is rapidly increasing toward the close of fetal life and that the rate of increase is maintained until the middle of the first year of postnatal life. At this time it stops its rapid growth abruptly and the absolute values decrease until nearly the end of the second year. Very late in the second year it again begins to increase, maintaining a low rate of growth to maturity. No attempt has been made to fit this curious curve and no

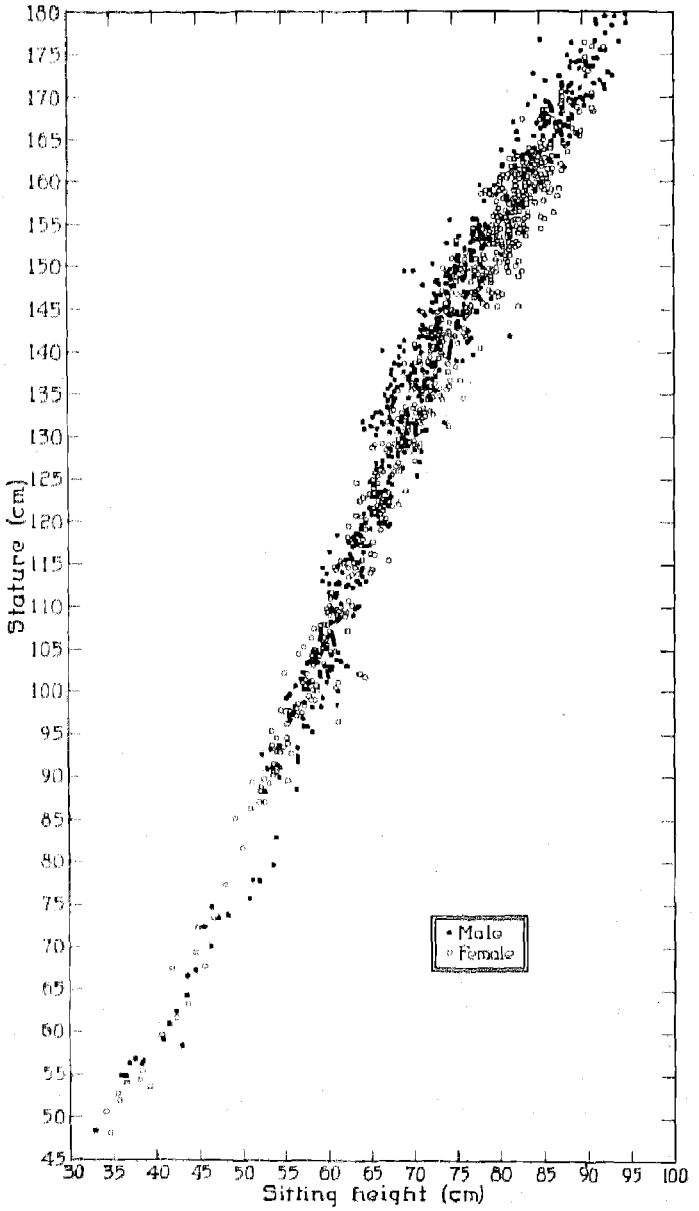

Figure 14. Stature plotted against sitting height, from approximately the sixth fetal month to maturity.

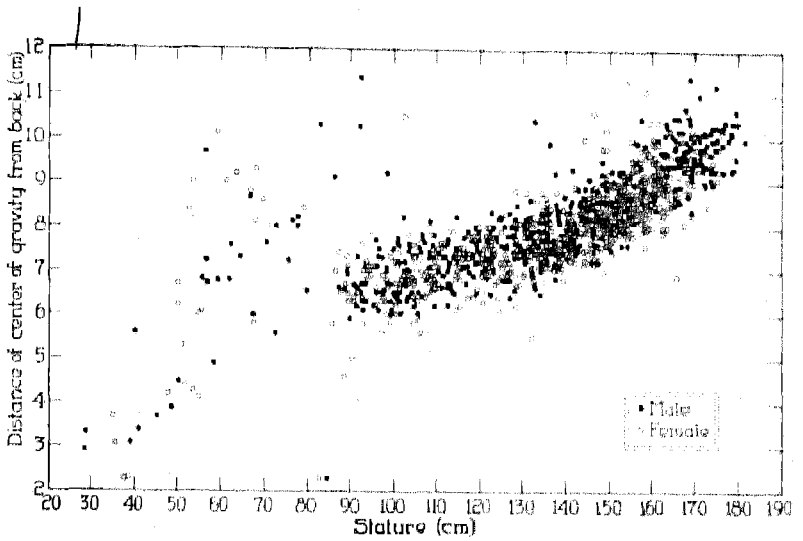

Figure 15. The distance of the center of gravity from the back plotted against stature, from approximately the sixth fetal month to maturity.

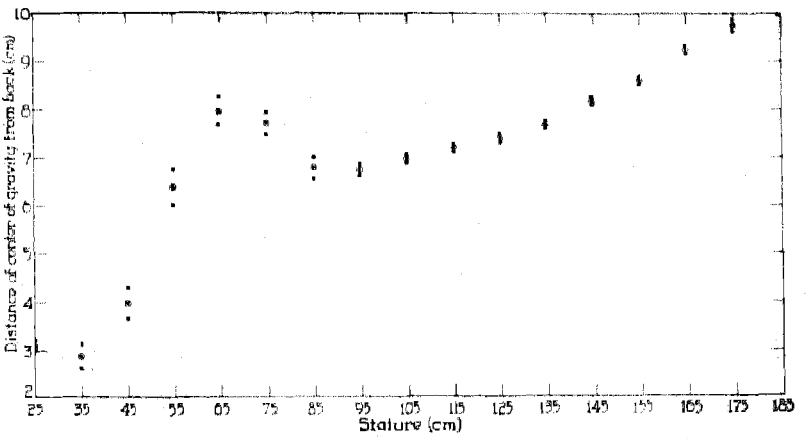

Figure 16. The mean distances of the center of gravity from the back, for 10 cm. intervals of stature, plotted against stature. The encircled dots represent the means and the smaller dots the probable errors of the means.

Table 18

Means and variability for intervals of stature of distance of frontal plane of gravity from back

(males)

Interval of stature (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
20- 30	2	3.10 ± 0.10	0.20	6.45
40- 50	5	3.94 ± 0.29	0.96	24.44
50- 60	6	6.32 ± 0.36	1.31	20.74
60- 70	5	7.28 ± 0.30	1.00	13.74
70- 80	8	7.40 ± 0.22	0.92	12.48
80- 90	5	7.26 ± 0.29	0.96	13.16
90-100	31	6.86 ± 0.11	0.90	13.11
100-110	62	7.00 ± 0.05	0.53	7.50
110-120	52	7.20 ± 0.04	0.43	5.93
120-130	54	7.50 ± 0.05	0.49	6.49
130-140	91	7.76 ± 0.04	0.60	7.76
140-150	103	8.15 ± 0.03	0.49	5.95
150-160	57	8.64 ± 0.05	0.57	6.62
160-170	70	9.52 ± 0.05	0.61	6.37
170-180	46	9.82 ± 0.05	0.54	5.53
180-190	1	10.00 ± -	-	-

Table 19

Means and variability for intervals of stature of distance of frontal plane of gravity from back

(females)

Interval of stature (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
20- 30	-	- -	-	-
30- 40	4	2.85 ± 0.23	0.68	23.86
40- 50	1	4.20 ± -	-	-
50- 60	11	6.43 ± 0.40	1.98	30.79
60- 70	7	8.40 ± 0.31	1.21	14.40
70- 80	3	8.63 ± 0.23	0.60	6.95
80- 90	10	6.55 ± 0.17	0.82	12.44
90-100	32	6.58 ± 0.08	0.69	10.46
100-110	51	6.91 ± 0.07	0.71	10.33
110-120	34	7.18 ± 0.06	0.52	7.21
120-130	55	7.31 ± 0.05	0.54	7.43
130-140	67	7.63 ± 0.05	0.57	7.50
140-150	94	8.15 ± 0.05	0.69	8.41
150-160	130	8.59 ± 0.03	0.58	6.78
160-170	75	9.00 ± 0.05	0.63	7.00
170-180	9	9.47 ± 0.16	0.72	7.65
180-190	-	- -	-	-

Table 20
Means and variability for intervals of stature of distance of frontal plane of gravity from back
(both sexes)

Interval of stature (cm.)	Number of cases	Mean and probable error (cm.)	Standard deviation (cm.)	Coefficient of variability (percent)
20- 30	2	3.10 ± 0.10	0.20	6.45
30- 40	4	2.85 ± 0.23	0.68	23.86
40- 50	6	3.98 ± 0.24	0.88	22.11
50- 60	17	6.39 ± 0.29	1.74	27.23
60- 70	12	7.93 ± 0.18	0.90	11.34
70- 80	11	7.74 ± 0.13	0.62	8.01
80- 90	15	6.78 ± 0.14	0.78	11.50
90-100	63	6.72 ± 0.08	0.79	11.75
100-110	113	6.96 ± 0.04	0.61	8.76
110-120	86	7.19 ± 0.03	0.46	6.40
120-130	109	7.40 ± 0.03	0.51	6.89
130-140	158	7.70 ± 0.03	0.59	7.66
140-150	197	8.15 ± 0.02	0.59	7.24
150-160	187	8.61 ± 0.02	0.57	6.62
160-170	145	9.25 ± 0.02	0.47	5.08
170-180	55	9.76 ± 0.04	0.50	5.12
180-190	1	10.00 -	-	-

Table 21
Significance of sex differences of height of center of gravity as determined by probable errors of means for intervals of stature

Interval of stature (cm.)	Diff. of means $M_{m.} - M_{f.}$ (cm.)	P. E. of diff. (cm.)	Ratio $\frac{\text{Diff.}}{\text{P. E. of diff.}}$
50- 60	-0.11	0.50	0.22
60- 70	-0.12	0.43	2.60
70- 80	-1.23	0.32	3.84
80- 90	+0.71	0.34	2.09
90-100	+0.28	0.14	2.00
100-110	+0.09	0.09	1.00
110-120	+0.02	0.07	0.30
120-130	+0.19	0.07	2.71
130-140	+0.13	0.06	2.17
140-150	0.00	0.06	0.00
150-160	+0.05	0.06	0.83
160-170	+0.52	0.07	7.43
170-180	+0.35	0.17	2.06
180-190	-	-	-

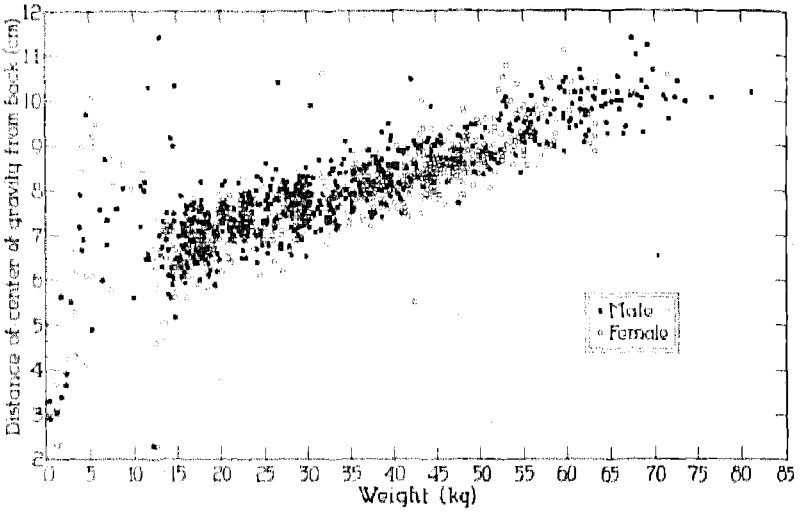

Figure 17. The distance of the center of gravity from the back plotted against body weight, from approximately the sixth fetal month to maturity.

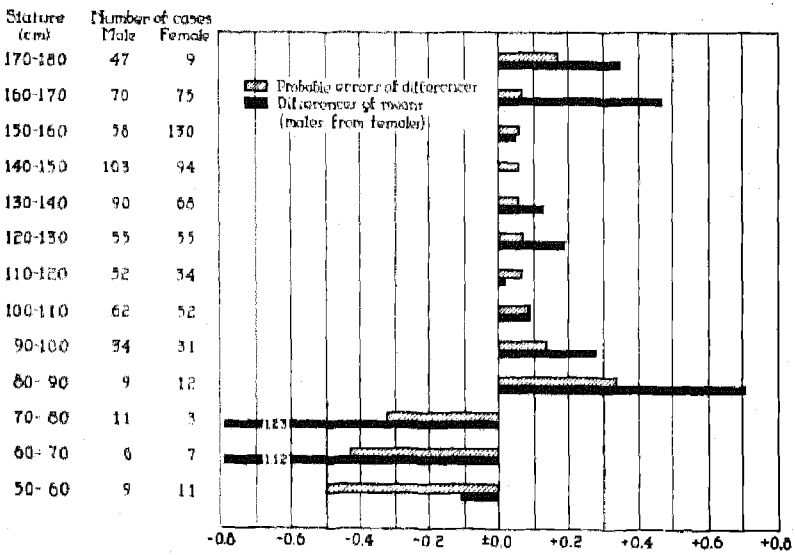

Figure 18. The significance of sex differences of the distance of the center of gravity from the back, as determined by the differences and probable errors of the means for intervals of stature. The positive side of the scale shows that the distance for males is greater and the negative side that the distance for females is greater.

satisfactory explanation can be offered for it. Figure 17, a field graph of this measurement plotted against body weight, shows a similar trend indicating that essentially the same relationship is maintained for both height and weight.

The result of a study of sex differences in the frontal plane of gravity is shown in Table 21 and Figure 18. The table shows the differences and probable errors of the differences of the mean distance of the center of gravity from the back for 10 cm. intervals of stature. The same facts are graphically illustrated in the figure. Significant differences are not definitely brought out, but the same general facts are indicated as were found for the transverse plane. It is probable that the center of gravity is slightly further from the back in males than in females, for the period during which stature ranges from 150 cm. to 170 cm. The effects of slight differences in stature within 10 cm. intervals are not considered significant in this analysis.

The dimensions of the trunk at the level of the transverse plane of gravity are not available. However, measurements of the transverse and anteroposterior diameters of the chest and pelvis have been made, and, although they do not represent the precise section of the body involved, it is desirable to make certain comparisons. In Figure 19 the anteroposterior diameter at the apex of the costal angle is plotted against stature and in Figure 20 the sacro-pubic, or external conjugate, diameter is plotted against stature. Upon both of these field graphs the mean distances of the frontal plane of gravity for intervals of stature are shown. Both of these diametral measurements follow simple regular progressions and give no clue to the definite inflections seen in the curve representing the distance of the center of gravity from the back.

The Anatomic Position of Center of Gravity

Griffith has shown that when the fetal body is placed in the normal intrauterine position its center of gravity lies approximately at the "site of entrance of the vena cava into the heart." Solis, working with two full term newborn bodies, determined the center of gravity in both the intrauterine and supine positions. In the former position Solis found that the transverse plane crossed the body 0.5 cm. below the tip of the xiphoid, ventrally, and between the spines of the eighth and ninth thoracic vertebrae, dorsally. In the supine position this plane shifted from 2 to 2.5 cm. caudally where it crossed the body dorsally at the tip of the tenth thoracic spine. In the latter position the center was found to lie 3.7 cm. from the dorsimesal surface of the body. A somewhat similar investigation was made upon two

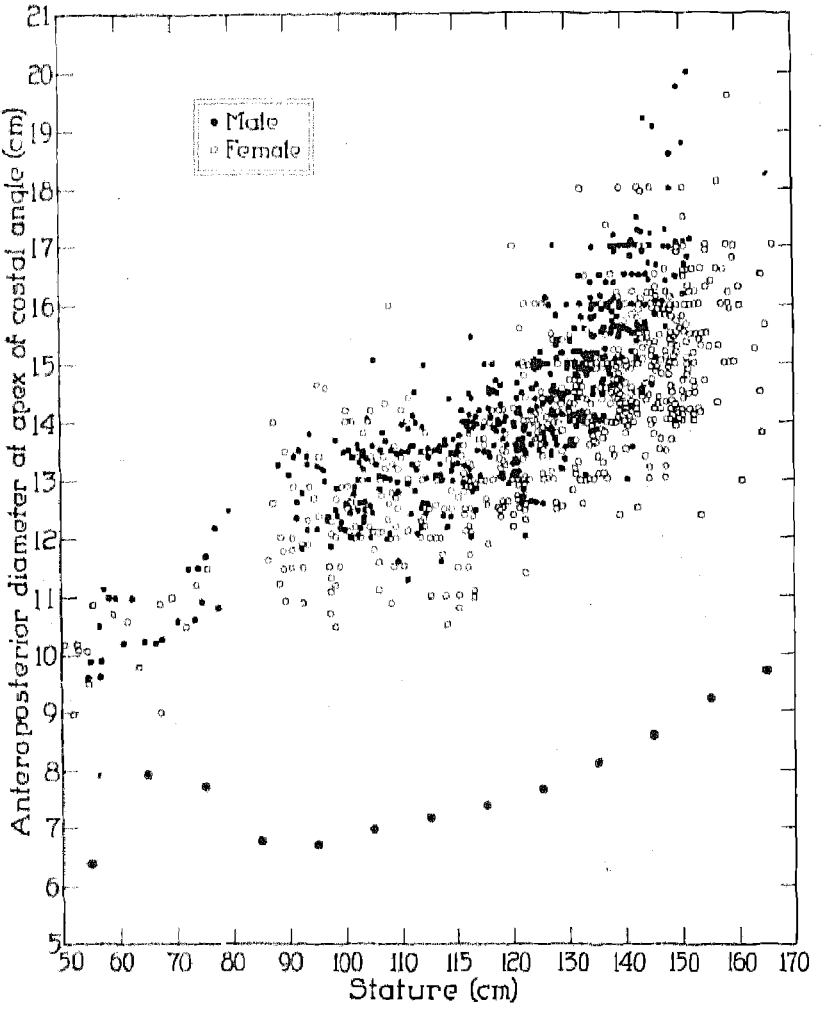

Figure 19. The anteroposterior diameter of the chest at the apex of the costal angle plotted against stature. The large encircled dots in the lower part of the field represent the mean distance of the center of gravity from the back for the same intervals of stature.

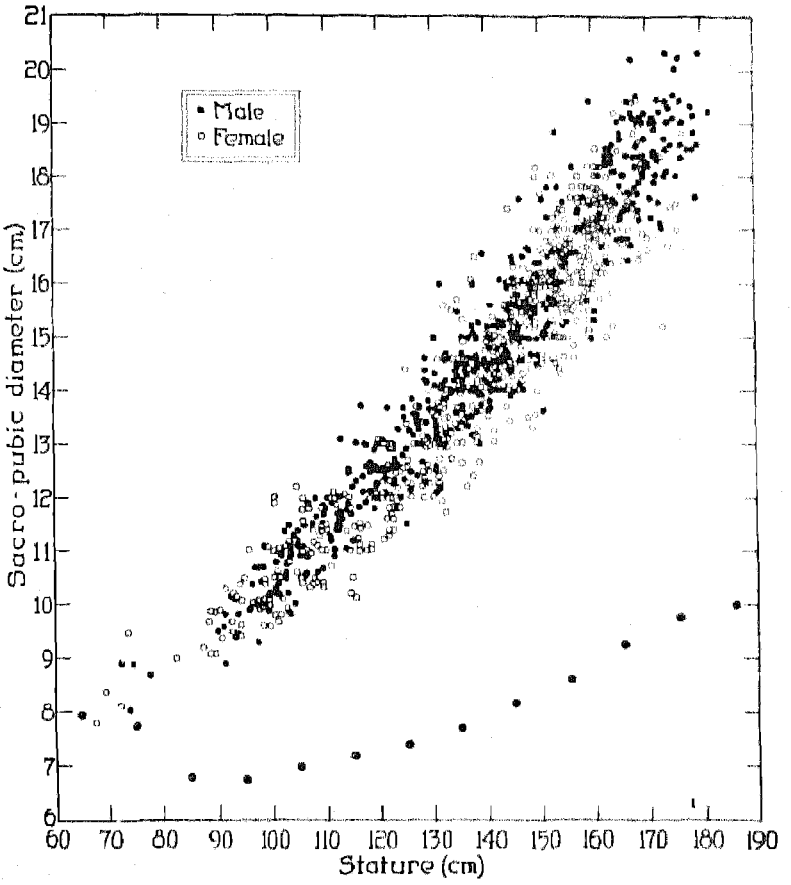

Figure 20. The anteroposterior diameter of the pelvis (sacro-pubic diameter) plotted against stature. The large encircled dots in the lower part of the field represent the mean distances of the center of gravity from the back for the same intervals of stature.

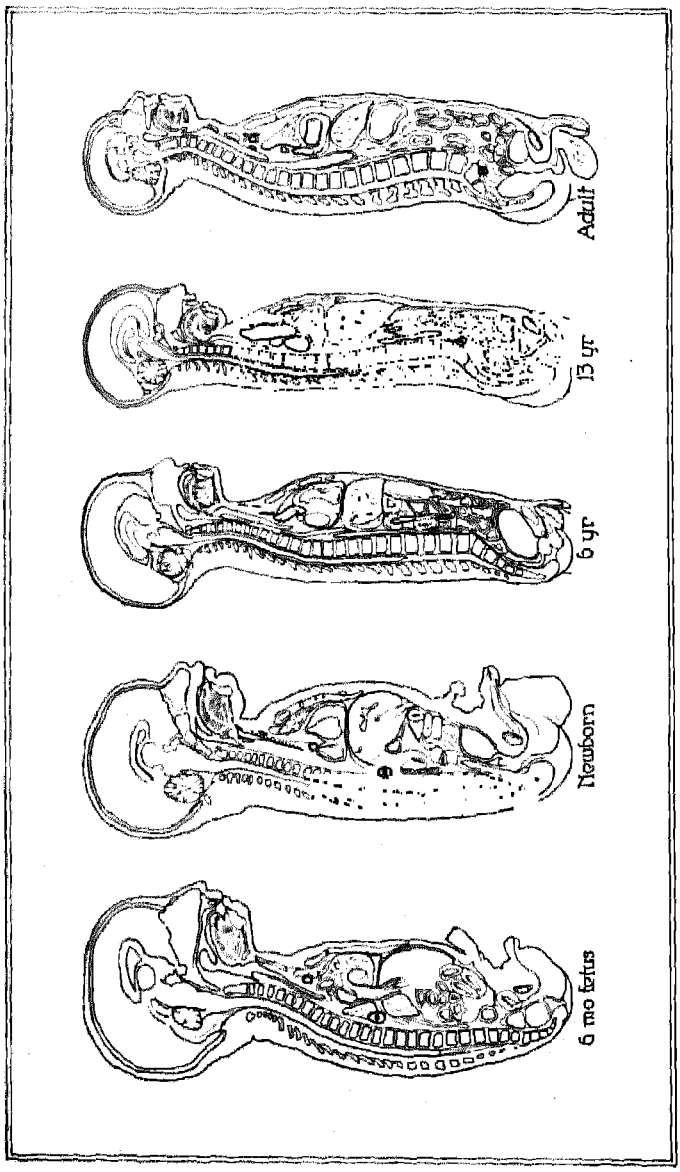

Figure 21. Five midsagittal drawings of the body at intervals from the sixth fetal month to maturity. The large solid dot indicates the mean position of the center of gravity. The ellipse drawn around each dot represents the "probable area" of the center of gravity as determined by three times the probable errors of the mean position of the center of gravity.

full term newborns in the present study. Orientation measurements and center of gravity determinations were made with the body in the supine position. Subsequent dissections and measurements of these specimens were made to locate anatomically the actual center of gravity. In both instances the center was found to lie just anterior to the intervertebral disc between the tenth and eleventh thoracic vertebrae in the immediate vicinity of the anterior margin of the aortic hiatus in the diaphragm. In one specimen the distance from the center of gravity to the posterior surface of the body was 3.7 cm., in the other it was 4.4 cm. The bodies used for this work are indicated in Table 11, where a detailed record of their dimensions is given.

Observations upon the actual location of the center of gravity at other times during the growth period are not found in the literature except for the few measurements upon adults made by Meyer, and Braune and Fischer. Meyer estimated by means of his approximation method that the center of gravity in the adult lies in the canal of the second sacral vertebra. Braune and Fischer's examination of the body showed that the actual center was located either within or just in front of the second or third sacral vertebra.

The material now available permits an extension of the phase of the problem concerned with the anatomic location of the center of gravity, Figure 21.

A series of drawings of the midsagittal plane of the body was obtained. The drawings selected were chosen because they represent either actual size or scale figures that accurately picture structures and relations. The series consists of 5 figures; a 6 months old fetus, a newborn child, a child of 6 years, a child of 13 years, and a mature adult. The midsagittal views of the 6 and 13 year old children were obtained from the actual size drawings of Symington ('87). The fetus and newborn figures were taken from Merkel ('94), and the adult figure, after Merkel, from Braune.

Sufficient data were furnished with each figure to make possible a fairly accurate estimation of the actual position of the center of gravity. The location of the center was determined upon the basis of the analytical equation derived above and upon the mean distances given in Tables 14 and 20. The calculated values were reduced to the proper scale and the measured position of the center was marked directly upon the original plates. In addition to the center of gravity, the variability of the center was shown in the following manner. The probable error of the array (0.6745 times standard deviation) for each mean in both the transverse and frontal planes was

determined from Tables 14 and 20. The positive and negative values of these probable errors were then marked on both the transverse and horizontal planes and the four points obtained were joined by means of a smooth curve. The range of one probable error about each center of gravity was thus indicated by an elliptical area. This 'probable area' takes the form of an ellipse because of the differences in variability of the two planes of gravity. The long axis of the ellipse is vertical, which pictorially demonstrates that the variability of the transverse plane of gravity is greater than the variability of the frontal plane. These figures were photographed directly from the original plates and accurate scale drawings subsequently made from the negative films by means of a photographic enlarging and reducing apparatus. Figure 21 shows this series of figures all drawn to the same crown-rump length.

This graphic method of presentation not only shows the actual anatomic location of the center of gravity but also gives a clear demonstration of the variability of the center of gravity and of the accuracy with which the present method may be applied to the study of living individuals. It is shown from the figures that the center of gravity at the sixth fetal month (body placed in the supine position) lies ventral to the body of the seventh dorsal vertebra in the lower part of the thoracic cavity above the diaphragm. In the newborn infant the center has shifted slightly and lies along the ventral border of the aorta where that vessel passes through the diaphragm and at this time is at the level of the intervertebral disc between the tenth and eleventh thoracic vertebrae. By the sixth year of postnatal life it has descended through the abdominal cavity to the lower level of the third lumbar vertebra, and probably lies within the aorta. During the thirteenth year it is situated just ventral to the promontory of the sacrum. In the adult body the center has definitely dropped into the pelvis and is located practically upon the ventral surface of the first segment of the sacrum.

It is thus shown that the center of gravity occupies a position above the dome of the abdominal cavity during the later months of prenatal life. During the remainder of the growth period it slowly descends through the full length of the abdominal cavity to finally take a position just over the brim of the pelvis in the adult body. During the whole of this time the center appears to lie fairly close to the ventral border of the vertebral column. In very general descriptive terms, it may be said that the center of gravity in the newborn is situated at the origin of the abdominal division of the aorta and that during growth it descends through the bifurcation of the aorta, to a

position just over the brim of the pelvis.

The descent of the center of gravity during growth furnishes another striking example of the "law of developmental direction." Changes in the center of mass reflect the complex results of the growth of all parts of the body and indicate that the growth of the body as a whole follows the same general law which governs the growth of nearly all its parts.

GENERAL SUMMARY

The available published data on the position of the center of gravity in the human body and on methods for locating the center have been briefly reviewed.

A method and apparatus have been developed for determining two planes, the transverse and frontal, which pass through the center of gravity in the living human body. The method is applicable to individuals of all ages, it requires very little cooperation of the subject, and permits the complete execution of a determination in less than five minutes.

The precision of the method and apparatus has been tested experimentally upon inert objects and living individuals. It was found that the center of gravity can be located within a circle of 0.75 mm. in diameter in inert objects, and can be located in the living human body with the same precision that standing height and sitting height can be measured.

A quantitative analysis of the position of the center of gravity has been based upon the study of 1200 individuals whose ages range from 6 fetal months to 20 years. The following data were secured upon nearly every living individual: name, sex, age, weight, body length, stature, sitting height, pubic height, arm length, leg length, the transverse and anteroposterior diameters of the head, chest, and pelvis, and the distance of the center of gravity from the soles and from the back.

The distance of the center of gravity above the soles, expressed as an index or per cent of stature, maintained a fairly constant ratio, which ranged from 55.0 to 59.0, during the whole of the developmental period. The coefficient of correlation, r, between the distance of the center of gravity above the soles and stature was of the order of .99. The most precise statement of the relationship between this distance and stature was expressed by the analytical equation:

$$y = 0.557x + 1.4 \text{ cm.}$$

where y equals the distance of the center from the soles, and x equals stature. The relationship was definitely rectilinear and the variability around the regression line was low.

The close association of the position of the transverse plane of gravity and stature was reflected in the other relationships studied; these included age, weight, sitting height, leg length, and pubic height. In this connection, the center of gravity was found to lie 20 cm. above the trochanter in the newborn body and 10 cm. above the trochanter in the adult body.

The distance of the frontal plane of gravity from the back showed a rapid increase during the latter part of fetal life. This increase continued until a temporary maximum of approximately 8 cm. was reached at about the middle of the first year. The period following, during which stature increased from 65 cm. to 95 cm., was marked by the shortening of the distance to slightly less than 7 cm. The distance of the center of gravity from the back showed a slow, regular, increase during the remaining portion of the growth period. The same general trend was observed in the relation between the distance of the center of gravity from the back and body weight. No explanation can be offered for the inflections of these curves.

The grouping of the data according to sex permitted a statistical analysis which showed that the center of gravity was very slightly, but significantly, higher and further from the back in males than in females during the approximate period in which stature increased from 145 cm. to 165 cm.

Changes in the anatomic position of the center of gravity have been shown by means of a series of midsagittal figures upon which the probable area' of the centers have been drawn. The descent of the center from the level of the seventh dorsal verbrate to the level of the first sacral vertebra was illustrated and described.

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Table 9

Observations upon the transverse and frontal planes of gravity, age, weight, stature, pubic and sitting heights, arm and leg lengths and anteroposterior and transverse diameters of the pelvis and chest for living subjects

Age	Weight	Stature	Sitting height	Pubic height	Arm length	Leg length	Diameters				Planes of gravity		
							Transverse Pelvis	Chest	Anteroposterior Pelvis	Chest	From soles	From back at 25°	at 30°
(yr-mo)	(kg)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
17- 9	73.65	181.6	98.1	-	-	-	29.5	26.6	19.2	21.1	103.1	10.0	10.1
17- 7	81.04	179.4	94.9	-	-	-	28.4	31.2	18.6	20.9	100.4	10.1	10.3
17- 8	64.53	179.1	93.6	-	-	-	27.0	25.8	17.5	17.0	99.8	9.3	9.7
16- 8	69.51	179.1	92.4	56.7	82.6	97.4	27.9	28.3	20.3	20.2	100.6	10.7	10.7
25- 9	68.61	178.8	80.0	-	-	-	-	-	-	-	102.6	9.5	9.0
17- 1	66.91	178.8	91.7	55.6	79.8	97.1	27.7	27.5	18.8	19.5	99.8	9.2	9.4
18- 4	76.90	178.4	94.9	-	-	-	28.0	28.5	18.5	19.2	99.7	10.0	10.3
16- 9	68.38	178.4	91.7	53.3	78.0	93.5	26.5	27.5	19.1	21.0	100.4	10.2	10.6
17- 0	65.72	178.1	93.3	51.4	81.5	94.0	26.3	26.8	19.3	19.3	97.3	10.2	10.3
19- 1	68.27	177.2	92.7	-	-	-	29.3	28.0	18.5	17.0	99.3	9.8	10.2
18- 5	72.80	176.8	94.0	-	-	-	27.5	26.0	18.6	19.0	100.0	10.2	10.6
15- 6	62.43	176.8	91.4	54.5	78.8	93.0	27.7	26.0	19.0	21.0	97.9	9.3	9.3
16-11	53.24	176.5	85.1	48.7	79.2	100.3	25.1	25.0	18.3	18.4	100.8	9.7	10.1
15-10	61.58	176.2	88.6	56.6	78.8	96.1	23.0	24.7	19.4	19.6	98.6	10.1	10.3
16- 8	69.34	176.9	92.0	51.4	76.5	100.6	27.5	30.0	20.2	19.9	99.2	10.5	10.2
15- 2	71.87	176.3	92.7	53.5	79.8	93.8	13.8	21.3	18.0	17.5	98.6	9.7	10.1
17- 8	59.01	176.3	88.8	-	-	-	26.0	28.5	20.0	19.4	99.4	11.4	11.0
17- 4	66.23	174.9	88.2	54.9	80.9	95.7	27.6	25.5	19.5	17.8	99.4	9.9	10.1
19- 7	65.66	174.3	91.7	-	-	-	27.5	27.0	19.1	17.4	97.9	10.0	9.9
16-10	68.71	174.3	91.4	52.5	77.4	90.6	27.0	26.7	18.6	18.2	98.5	10.2	10.4
18- 2	63.28	174.0	88.9	-	-	-	27.2	27.5	18.4	16.6	99.6	10.3	10.4
15- 7	58.00	174.0	89.5	55.1	78.4	95.9	27.0	27.8	19.0	18.0	101.7	8.7	9.2
18- 0	61.46	174.0	89.8	52.8	80.3	93.9	26.2	25.5	20.3	19.0	98.8	9.7	10.0
17- 4	66.74	174.0	90.5	52.9	78.9	91.6	28.6	27.5	18.7	20.0	96.8	9.3	9.4
17- 9	61.80	173.7	90.5	-	-	-	28.3	28.7	18.0	18.0	97.6	8.9	9.1
16-11	59.65	173.4	91.1	-	-	-	26.1	27.0	18.0	20.0	98.8	9.7	9.6
16- 4	64.36	173.4	90.8	51.4	78.1	90.7	27.0	28.3	18.5	19.8	97.7	10.2	10.1
15- 7	64.92	173.4	88.6	54.3	79.9	94.7	27.5	28.5	19.4	20.7	98.6	9.2	9.5
17- 8	56.47	173.4	89.8	-	-	-	26.7	25.5	17.0	17.7	97.5	9.3	9.2
17- 4	71.10	172.7	93.0	-	-	-	26.8	29.0	17.0	18.3	96.3	9.9	10.3
17-10	61.84	172.4	93.3	-	-	-	26.0	27.5	17.5	19.0	96.5	9.7	10.1
16- 0	60.22	172.4	84.4	56.3	78.0	97.9	26.0	26.0	19.4	18.7	97.7	9.3	10.0
17- 2	56.93	172.1	90.5	-	-	-	24.9	24.8	18.3	17.5	96.5	8.9	9.2
16- 7	58.86	172.1	89.2	52.7	77.3	91.0	26.0	26.4	18.4	17.8	95.9	9.0	9.0
16- 3	57.72	172.1	87.3	51.4	78.1	92.7	25.0	27.0	19.2	18.6	97.2	10.1	9.5
16- 2	57.70	171.8	92.0	56.7	76.8	90.6	26.2	26.0	18.9	19.1	95.7	10.1	10.1
18- 6	62.14	171.5	85.7	-	-	-	27.7	27.2	17.9	18.3	97.6	9.8	9.6
16- 5	54.66	171.5	83.8	56.1	80.2	96.5	25.2	25.5	18.0	19.4	98.5	8.3	8.6
18- 0	57.30	171.5	91.4	-	-	-	27.0	26.0	18.5	17.4	96.7	10.0	10.2
15- 9	59.45	171.5	88.6	51.7	76.3	92.6	25.4	26.0	18.4	17.6	95.7	9.1	9.6
14- 2	52.84	171.1	88.6	49.3	75.4	90.0	25.4	26.6	19.0	18.8	96.7	9.5	9.4
16- 2	51.31	171.1	92.4	49.4	78.5	87.0	25.6	24.2	17.6	17.8	94.5	8.5	9.1
14- 3	56.53	171.1	87.6	51.2	76.7	91.1	24.9	26.6	19.1	18.0	96.3	9.7	9.5
17- 4	65.04	171.0	88.2	50.0	80.9	90.7	28.2	27.7	19.0	19.1	96.7	10.1	9.9
18- 1	58.69	170.8	89.8	-	-	-	26.5	27.3	17.2	18.0	97.4	9.8	9.9
16-10	58.04	170.8	92.7	-	-	-	25.7	28.5	18.3	19.3	95.3	11.1	10.8
16- 9	60.27	170.5	88.2	51.4	74.6	90.6	25.9	26.0	18.2	19.3	95.5	9.4	9.6
16- 8	63.05	170.2	88.9	50.0	73.3	89.6	27.0	26.0	19.2	18.5	95.0	9.8	10.5
18- 6	71.58	169.9	91.1	-	-	-	25.6	28.0	18.7	19.0	94.8	9.3	9.9
15- 8	53.53	169.9	84.4	54.7	80.3	95.1	25.3	23.0	18.3	18.0	97.4	9.4	9.7
17- 9	64.64	169.9	89.8	-	-	-	26.0	29.2	18.2	18.3	95.1	9.4	10.7
15- 4	55.62	169.9	90.5	-	-	-	26.4	26.0	18.0	19.0	95.1	9.4	9.6
14- 1	52.31	169.5	89.5	49.0	69.6	-	25.6	25.7	18.5	17.5	92.2	9.2	9.3
16- 3	50.46	169.5	83.8	52.3	76.9	93.1	27.5	25.7	18.1	14.8	96.0	8.2	8.6
17- 5	61.18	169.5	90.1	48.5	74.7	89.7	27.2	26.0	19.0	18.4	94.2	9.3	9.6
15- 8	55.17	169.5	88.2	48.8	77.8	90.9	25.5	24.5	17.2	18.8	94.1	9.0	9.3
18- 4	64.07	168.9	89.2	-	-	-	25.3	25.6	19.0	18.2	94.7	9.9	10.0
16- 6	61.46	168.9	86.0	-	-	-	26.0	26.3	18.4	18.0	95.7	10.7	10.2
14-11	66.11	168.9	89.8	-	-	-	26.0	28.0	17.9	19.0	95.3	9.6	10.0
15- 1	55.96	168.9	85.7	51.9	83.6	91.7	27.5	25.9	19.1	19.6	93.5	10.1	10.0
16- 6	59.42	168.9	90.1	47.6	78.6	89.0	26.8	27.0	18.4	16.5	95.4	10.1	10.7
14- 2	57.04	168.9	83.8	52.7	74.1	94.4	26.0	25.0	18.3	17.3	95.4	9.3	9.3
14- 1	57.30	168.6	86.3	-	-	-	27.7	27.0	18.2	19.8	96.6	11.8	11.0
16- 0	56.59	168.6	87.6	-	-	-	26.0	26.0	17.3	18.0	94.4	9.2	9.4
16-10	54.32	168.2	86.3	48.8	73.3	88.4	22.4	25.5	17.7	17.4	94.3	8.7	8.9
15- 4	58.54	168.2	85.4	52.1	74.1	92.2	26.2	24.7	18.6	18.5	95.0	9.5	9.3
14- 8	61.41	168.0	86.6	-	-	-	27.5	26.0	18.4	18.0	95.2	10.7	10.7
16- 3	54.89	167.6	87.3	-	-	-	26.7	25.0	17.8	18.0	95.1	9.3	9.4
18- 3	57.10	167.6	88.9	-	-	-	27.2	27.5	17.4	17.4	94.1	9.7	9.5
16- 5	61.41	167.6	85.7	48.7	74.8	88.7	25.7	27.0	19.5	19.0	94.4	10.0	10.0

CARROLL E. PALMER

Table 9 (Continued)

Age	Weight	Stature	Sitting height	Pubic height	Arm length	Leg length	Diameters				Plane of gravity		
							Transverse Pelvis	Chest	Anteroposterior Pelvis	Chest	From soles	From back at 25°	at 30°
(yr-mo)	(kg)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
16- 2	58.61	167.3	85.3	90.2	78.0	90.5	26.6	26.6	19.1	17.8	95.0	9.6	9.5
16- 8	60.56	167.3	88.9	-	-	-	26.5	26.0	17.5	18.0	95.2	9.7	9.5
14-11	54.43	167.3	85.4	91.1	77.1	91.7	25.3	25.1	17.7	17.6	95.0	9.8	9.8
15- 9	63.62	167.0	88.2	-	-	-	27.0	28.5	19.2	19.2	95.6	9.4	9.6
15- 4	59.82	167.0	87.0	88.2	74.0	88.9	26.3	25.0	-	19.8	96.4	10.2	10.2
13- 3	45.88	167.0	82.2	93.2	76.1	95.4	26.4	22.6	16.7	16.3	95.4	8.6	-
17- 2	63.22	166.8	86.0	89.2	73.4	87.9	28.3	29.8	18.4	18.4	93.4	10.2	9.8
14- 6	59.65	166.7	86.3	88.7	74.1	89.6	26.0	29.8	20.2	18.2	93.3	9.8	9.7
15- 7	59.88	166.7	85.7	90.5	76.2	90.7	25.7	25.6	18.4	17.4	92.8	8.6	9.0
17- 1	55.23	166.4	87.9	-	-	-	26.0	26.0	17.4	16.6	93.9	9.5	9.6
13- 9	52.39	166.4	84.7	88.7	75.7	90.0	24.6	24.7	17.7	16.7	93.1	8.4	8.8
14- 9	61.07	166.4	85.4	88.9	73.3	90.3	26.2	26.4	19.4	19.3	93.4	10.2	10.2
16- 8	66.89	166.4	88.2	86.6	73.1	86.7	28.9	29.6	16.8	-	94.3	10.6	10.4
16- 2	57.56	166.1	85.1	88.5	75.1	87.2	26.0	25.7	18.0	17.1	92.1	9.3	9.5
17-10	55.79	165.7	87.3	-	-	-	26.0	28.0	16.8	18.0	92.4	9.8	9.7
14- 2	57.72	165.7	89.5	84.6	70.5	84.6	27.0	27.8	19.1	19.4	92.4	9.9	10.1
16- 8	54.32	165.7	87.3	87.3	74.1	87.5	25.5	25.7	18.0	19.0	92.1	9.1	9.4
15-11	49.30	165.4	87.0	86.4	74.4	86.4	25.8	25.6	17.3	18.5	92.0	8.8	8.7
14- 3	47.63	165.4	87.0	88.7	73.9	90.7	25.1	24.5	17.2	16.3	93.1	8.5	8.9
18- 2	60.67	165.1	88.6	-	-	-	28.2	25.3	17.6	17.9	92.1	9.6	10.1
16- 2	59.93	165.1	85.4	-	-	-	27.2	25.4	17.8	19.0	94.1	10.6	10.4
14- 4	57.97	165.1	88.5	87.7	72.3	90.1	26.5	25.8	17.2	18.0	92.5	8.9	8.8
16- 3	61.69	165.1	84.4	87.3	71.9	86.9	27.1	27.0	18.8	18.0	92.5	9.5	9.6
18- 4	49.67	164.8	82.5	90.4	74.2	91.8	26.0	24.5	16.8	16.8	94.0	8.3	8.5
17-10	72.58	164.8	87.6	-	-	-	28.9	28.5	19.0	20.1	93.0	10.1	10.1
16- 7	60.80	164.5	86.3	85.7	68.6	86.3	24.4	26.2	18.1	16.3	91.1	9.5	9.3
17- 7	51.92	164.5	88.2	-	-	-	25.2	26.0	17.5	20.6	92.4	8.6	8.9
16- 8	59.31	163.8	84.4	-	-	-	26.3	26.5	17.6	18.3	92.9	10.2	10.4
15- 4	53.78	163.8	86.6	88.7	75.3	89.2	26.4	24.2	18.6	17.5	92.4	9.1	9.6
15- 6	54.66	163.2	82.8	89.7	74.7	90.5	24.0	24.6	18.3	19.2	92.5	9.6	9.7
15- 2	50.24	163.2	85.1	87.2	84.8	87.2	26.7	23.0	18.2	17.1	92.6	9.1	9.3
15- 4	57.04	163.2	83.8	87.9	74.0	89.9	26.2	26.0	18.3	19.5	92.0	10.4	10.5
18- 8	52.14	162.9	87.0	-	-	-	26.6	27.7	18.2	18.5	92.8	9.1	9.8
14- 5	53.13	162.6	83.2	87.4	72.3	88.9	25.6	25.0	18.5	17.3	91.4	10.1	10.0
14-11	50.62	162.6	83.2	87.5	74.6	88.7	27.4	24.0	18.5	16.8	92.3	8.8	9.0
17- 5	48.89	162.6	84.1	-	-	-	23.5	25.6	16.9	15.5	91.9	9.2	9.7
15- 9	49.44	162.6	84.4	86.1	73.2	85.7	25.0	26.0	17.6	16.8	91.5	8.7	9.3
14- 6	52.62	162.6	86.0	84.0	72.2	83.7	24.0	26.0	18.5	17.0	91.8	9.8	9.5
15-10	52.62	162.2	86.1	83.3	74.8	84.7	26.3	24.8	18.3	16.5	91.3	9.0	8.8
15-10	48.08	161.3	80.6	88.6	71.3	89.0	24.5	24.2	17.5	16.3	92.0	9.1	9.3
14- 2	53.24	161.3	82.2	86.3	73.3	89.4	25.3	24.0	17.3	19.3	90.4	9.9	10.1
16- 1	51.31	161.3	87.6	83.0	74.9	82.5	25.0	25.5	17.0	20.0	92.8	8.8	8.9
13-11	45.36	161.3	80.6	88.7	71.5	90.4	24.6	24.2	16.7	16.8	93.4	9.1	9.2
14- 7	47.06	161.0	82.2	85.7	74.2	86.7	24.7	24.5	18.2	17.1	91.3	8.8	9.0
14- 8	49.95	161.0	84.1	82.5	73.5	86.8	25.3	25.1	17.2	16.7	90.4	8.2	8.6
17- 3	49.44	161.0	83.8	85.1	74.0	86.8	25.0	26.5	18.0	18.8	94.0	9.2	9.8
13-11	45.42	160.9	83.2	85.1	72.2	85.9	24.6	24.0	15.5	17.0	90.9	9.0	9.4
13-10	46.21	160.7	83.2	84.1	72.4	86.4	24.0	24.2	15.3	16.2	90.8	8.5	9.0
16- 5	51.03	159.7	85.1	84.7	73.9	85.5	27.1	23.0	17.9	17.0	89.0	8.6	8.8
14- 0	51.65	159.4	78.1	89.1	69.4	88.7	23.6	25.5	19.4	19.7	91.9	8.6	8.8
17- 6	44.34	159.4	83.8	-	-	-	23.9	23.2	15.0	16.5	89.9	8.7	8.6
15- 9	41.39	159.4	80.0	-	-	-	23.5	23.5	15.6	14.0	91.6	8.4	8.5
15- 5	47.80	158.8	84.7	82.2	69.8	84.7	24.5	25.0	17.1	17.0	90.1	8.4	9.4
16- 8	51.03	158.8	79.7	87.7	70.7	88.5	23.5	24.1	17.6	14.6	90.9	8.8	8.9
15- 7	44.51	158.1	80.0	84.6	73.4	86.9	25.3	22.6	17.0	18.0	90.5	8.7	9.1
14- 8	47.14	157.8	81.3	84.1	71.7	86.0	24.0	24.5	16.6	17.3	89.7	8.4	8.9
18- 7	41.96	157.8	81.5	82.6	67.5	84.6	22.9	23.0	17.3	16.4	89.0	10.2	10.6
17- 5	41.85	157.5	78.7	86.0	70.3	87.3	23.6	23.6	16.6	15.6	89.6	8.2	8.4
16- 9	47.29	157.5	83.2	82.2	70.1	84.5	25.5	26.7	17.3	17.0	89.3	9.3	9.5
18-10	44.11	157.5	83.2	81.6	68.6	85.9	23.4	22.5	17.0	16.0	88.3	8.9	9.3
15- 5	49.16	157.2	82.5	81.9	69.1	84.0	25.4	24.0	18.2	19.0	88.3	9.7	9.3
14- 2	44.45	156.5	81.4	79.4	70.7	83.5	24.2	25.0	16.5	15.4	87.6	10.0	9.8
17- 5	43.38	155.9	80.6	81.6	69.5	83.8	21.6	22.5	16.5	16.6	87.1	8.7	9.4
13-10	44.04	155.6	77.8	85.5	69.1	86.7	23.8	24.6	16.5	16.0	88.8	7.9	8.5
18- 7	42.47	155.2	74.9	88.2	69.0	87.0	23.8	24.4	16.4	-	88.2	9.3	9.1
17- 1	43.48	154.9	77.8	82.4	69.7	84.0	23.7	24.1	15.2	15.0	86.6	8.2	8.3
14- 4	47.52	154.9	78.0	83.9	68.8	85.7	25.1	25.5	15.5	17.2	87.8	9.7	9.5
13- 3	39.35	154.9	78.1	83.1	67.5	84.6	24.0	23.4	16.0	14.7	87.7	7.6	7.7
18- 6	42.00	154.6	81.6	81.1	68.1	82.0	23.4	23.0	17.5	16.7	87.1	8.8	9.5
10-11	36.74	154.3	77.1	81.6	69.3	84.5	23.0	22.0	15.2	16.5	88.9	8.6	8.4
11- 6	40.54	154.3	79.0	81.1	68.2	83.9	23.8	22.4	16.5	16.5	86.1	7.8	8.0
14- 2	40.71	154.3	77.5	79.8	69.0	82.4	23.0	25.6	16.3	14.2	86.7	8.2	8.3
13- 3	46.78	154.0	77.4	85.3	71.8	86.9	23.0	22.6	16.0	17.0	87.3	8.4	8.7
18-10	42.70	153.7	78.1	80.9	67.4	83.1	22.6	23.6	15.6	15.6	86.6	8.2	8.6
16-10	52.28	153.7	83.2	78.9	66.1	79.0	23.6	26.7	17.8	19.2	85.5	9.6	9.7
17-11	37.71	153.7	75.9	83.4	68.4	85.9	23.5	22.2	16.0	15.6	89.2	8.6	9.0
18- 9	41.28	153.7	81.6	79.1	69.3	80.0	25.0	23.4	16.6	15.6	85.1	7.7	8.3
18- 7	47.52	153.4	79.3	80.6	69.5	83.0	25.7	25.6	17.0	17.0	87.1	9.2	9.2
17- 3	43.66	153.0	77.4	80.5	71.0	83.6	24.0	23.5	15.7	16.0	85.7	8.6	8.8
15- 7	46.04	153.0	78.4	-	-	-	23.6	24.5	14.5	16.5	87.4	8.7	8.6